STUDIES ON PLANTATION BAMBOO

[*Bambusa bambos* (L) Voss]

T1644

Thesis submitted to the Bharathiar University
for the award of the Degree of
DOCTOR OF SCIENCE

By
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JULY - 2004

T1644

DECLARATION

I do hereby declare that the thesis entitled "STUDIES ON PLANTATION BAMBOO [*Bambusa bambos* (L.) Voss]" submitted to the Bharathiar University, Coimbatore, for the award of the Degree of Doctor of Science in Botany, is a record of original and independent research work done by me during September 1995 to June 2004 and I further certify that the thesis has not previously formed the basis for the award of any Degree other than a Master's Degree or Ph.D. Degree, Diploma, Associateship, Fellowship or other similar title.

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WHOMSOEVER IT MAY CONCERN

It is to certify that the research papers, articles and books mentioned and submitted for this D.Sc., thesis is mainly contributed by the work done by **Dr. P. Shanmughavel** during his Ph.D., and Post Doctoral Research activities. The percentage of contribution in the above mentioned research publications are more than 80%. The role of co-author is to guide and edit the manuscripts.

I have *no objection* in submitting these publications by Dr. P. Shanmughavel for the award of Doctor of Science.

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TO WHOMSOEVER IT MAY CONCERN

This is to certify that the research papers and books mentioned and submitted for the D. Sc. thesis is mainly contributed by the work done by Dr. P. Shanmughavel, Department of Botany, Bharathiar University, Coimbatore during his Post Doctoral Research activities. The major contribution in the above-mentioned publications is by him.

I have no objection in submitting these publications by Dr. P. Shanmughavel for the award of Doctor of Science.

18/6

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CERTIFICATE OF POST DOCTORAL RESEARCH

Dr. P. Shanmughavel joined the Department of Botany, Bharathiar university, Coimbatore 641 046 as Ph. D scholar and obtained his Ph. D in the field of Plantation Bamboo in 1995. He has studied the organic productivity, nutrient distribution, nutrient cycling, pulp and paper characteristics of plantation bamboo. Later he worked as CSIR- SRF (January, 1995- March 1997) and Research Associate (April 1997- March 2002 for post doctoral research. Then he joined as a guest faculty of bioinformatics in the Department of Botany, Bharathiar University, Coimbatore and continued his researches. He has nearly a decade of post doctoral research experience. In his post doctoral work, he continued researchers in the productivity and nutrient dynamics of the plantation bamboo crop upto ten years aged plantations. Further he investigated intercropping of bamboo plantations, agri-silvi-horticultural models, productivity and nutrient cycling of other forest plantations –*Bambusa vulgaris, Dendrocalamus strictus, Acacia holosericea, Leucaena leucocephala. Tectona grandis and Eucalyptus hybrid.* He also evaluated the bamboo plantations raised under afforestation, social forestry and community forestry programmes. He has visited the Xisuangbanna Tropical Botanical Garden as a Visiting Scientist for collaborative research with the Chinese Academy of Sciences, Kunming, Southwest China on Biomass and Nutrient cycling of tropical seasonal rain forests of Xishuangbanna. He obtained excellent results, which have been published and appreciated by researchers in the field. Besides, his findings are highly useful for raising bamboo as a plantation crop, reclamation and economic cultivation.

Currently, his research work involves the digitization and automation of data on tropical forests and developing database models for industrial plantations and forest informatics. Dr. P. Shanmughavel published more than 120 research publications in all and 6 books in reputed International and National journals. He has presented 20 research papers in several academic bodies, which have won the appreciation of everyone. He presented a paper on Establishment and management of bamboo plantations at the 15th Commonwealth Forestry conference, Zimbabwe sponsored by Commonwealth Forestry Association. The Tamil Nadu State Council for Science and Technology has honoured him with the prestigious Tamil Nadu Scientist Award (TANSA) in 2001. His book on regional language won the Best Book Award in the field of Agriculture in 2002 by the Government of Tamil Nadu.

12.07.04.

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PREFACE

Bamboo is a cultural feature of South and Southeast Asia. India shelters about 130 species occurring over an area of 10.03 million ha, which constitutes 12.8% of the total forest area of the country. Over-exploitation associated with growing human populations, gregarious flowering, destruction of tropical forests and new demands on the resources for industrial use, especially by the pulp and paper industry, have resulted in wide-scale decimation of bamboo stocks; from vast forests of bamboo in South and Southeast Asia at the beginning of the century, we are left with the current situation of acute scarcity. Many countries have been forced to severely restrict and in some cases even ban out right the harvesting and exporting of bamboos from natural forests.

However, demand for bamboo is increasing much more than their availability. The report on the National Commission on Agriculture (1995) brought out some figures about the current demand and output of the projected bamboo requirements for 2000 (7,005 million Cu. m) and 2005 (9,820 million Cu. m) and recommended the measures required to bridge the increasing gap between demand and supply. It was recognized that raising elaborate bamboo plantations and also using the existing natural bamboos judiciously and efficiently could only sustain the availability of bamboo resources. Systematic cultivation of bamboos and their scientific management can therefore, ensure sustainable production.

Efforts are therefore, directed towards the cultural and agronomic techniques which will boost bamboo production so that raw material in sufficient quantity can be made available to farmers, rural households and industries. However, very little is known about several aspects of this fascinating plant and these are receiving a high priority in the research activities of bamboo specialists. Thus bamboo biology, embryology, cytology, physiology of flowering, ecology, silviculture and utilization are all under detailed investigation.

Even the authentic identification of the different species of bamboos, which is basic to all studies, has to be undertaken with a sense of purpose.

In view of its multi-dimensional importance in various spheres, a thorough understanding of several factors related to bamboo growth, productivity, (biomass), anatomy, litter production, nutrient cycling and pulp and paper characters of the plantation bamboo has become necessary.

In such a condition of bamboo research, I have chosen the topic "*Plantation Bamboo*" for my doctoral research. An experimental trial of *Bambusa bambos* was conducted at Kallipatty, near Sathyamangalam, Tamil Nadu State, India. "Studies on organic productivity, nutrient distribution, nutrient cycling, pulp and paper characteristics of plantation bamboo [*Bambusa bambos* (L) Voss]" up to the age of six years formed the basis for doctoral research.

During my post doctoral research, work on the plantation bamboo was continued to record its further growth, recruitment of culms, organic productivity nutrient distribution, nutrient dynamics and pulp characters up to 10 years.

The post doctoral work also includes intercropping of bamboo plantations, agri-silvi-horticultural models, productivity and nutrient cycling of other forest plantations – *Bambusa vulgaris, Dendrocalamus strictus, Acacia holosericea, Leucaena leucocephala. Tectona grandis and Eucalyptus hybrid.* The bamboo plantations raised under afforestation, social forestry and community forestry programmes are also evaluated during the post doctoral period.

Then the Chinese Academy of Sciences invited as Visiting Scientist for the collaborative research with the Department of Forest Ecology, Xishuangbanna Tropical Botanical Garden, Kunming, Southwest China on Biomass and Nutrient cycling of tropical seasonal rain forests of Xishuangbanna. This work is related to the sub theme

of biomass and nutrient cycling and is also included in the thesis as additional papers.

The current work involves the digitization and automation of data on tropical forests and developing database models for industrial plantations and forest informatics.

During PDF I have published more than 80 research publications and 6 books in reputed International and National journals. I also presented 20 research papers in several academic bodies, which have won the appreciation of everyone. The paper on Establishment and management of bamboo plantations was presented at the 15th Commonwealth Forestry conference, Zimbabwe sponsored by Commonwealth Forestry Association. Recently, the Tamil Nadu State Council for Science and Technology has honoured him with the prestigious Tamil Nadu Scientist Award (TANSA). My book on regional language won the Best Book Award in the field of Agriculture in 2002 by the Government of Tamil Nadu.

The co authors Prof. K. Francis, Department of Botany, Bharathiar University, Coimbatore and Mr. Peddabiah of Institute of Wood Science and Technology issued letters stating that their no objection in submitting all the publications included in the thesis.

The summary of the out standing contribution to the literature based on the post doctoral research and the details of contribution to the society is given separately.

The thesis is mainly based on the papers, articles and books published during the post doctoral research.

DR. P. SHANMUGHAVEL

SUMMARY OF OUTSTANDING CONTRIBUTION TO THE LITERATURE OF PLANTATION BAMBOO BASED ON THE POST DOCTORAL RESEARCH ON WHICH THE THESIS IS BASED.

1. Systematic cultivation of plantation bamboo (*Bambusa bambos*) and its scientific management was suggested.
2. Methodology designed for biomass estimation and nutrient cycling for the plantation Bamboo (*Bambusa bambos).*
3. Nutrient cycling was reported first time in the plantation Bamboo (*Bambusa bambos).*
4. Felling cycle prescribed for the efficient use of plantation Bamboo (*Bambusa bambos).*
5. Harvesting methods and Post harvest application of fertilizers are recommended for *Bambusa bambos.*
6. Economics (cost: benefit ratio) of Bamboo cultivation (*Bambusa bambos)* is tabulated.
7. The problems and prospects of cultivation of bamboo (*Bambusa bambos)* suggested for the benefit of farmers.
8. Regression equations are derived and suggested first time for the plantation bamboo. This equation is very useful for the paper industries.
9. Cultivation of bamboo (*Bambusa bambos)* in the Social Forestry programme and the community forestry programme was investigated and the guidelines were suggested for the first time.
10. Suggestions for the efficient utilization of bamboo (*Bambusa bambos)* by the pulp and paper industries were made.
11. Comparisons of pulp and paper characteristics of bamboo (Bambusa bambos) with some tree species were made with aim to investigate the suitable alternative raw material to the paper industries.

12. With reference to the International Bamboo and Rattan Research (INBAR) suggestions, intercropping of agricultural crop and its growth, yield and land equivalent ratio (LER) of Pigeon Pea, Turmeric, Soybean and Ginger in bamboo plantations were tried. The aim of this study is to identify the suitable agricultural crops, which can be recommended for intercropping during the initial stages of raising bamboo plantation. The interaction between agricultural crops and plantation bamboo, nutrient cycling in agro forestry systems were also investigated and reported first time in this field.
13. A new agro forestry model entitled "Agri – Silvi – Horticulture was suggested first time for the benefit of farmers. This model is attractive both economically and ecologically for farmers interested in short- term returns and long term security.
14. The edible nature of *Bambusa bambos* was evaluated and suggested as raising this species as edible bamboo.
15. Developments of database models for industrial plantations are made.
16. Digitization and automation of data on tropical forests are also done. It will form a quick reference source for scholars, foresters, paper industries.
17. Biomass and nutrient cycling of other forest plantations were also investigated (*Acacia holosericea, Bambusa vulgaris, Dendrocalamus strictus, Tectona grandis, Leucaena leucocephala, Eucalyptus hybrid*).
18. The Chinese Academy of Sciences, China have invited as visiting Scientist for the collaborative research to work on biomass and nutrient cycling of a tropical seasonal rain forests of Xishuangbanna, South west china and several research papers are published.

19. 17. The Commonwealth Forestry Association. U K., sponsored to share my research experiences on the cultivation of bamboo and to present my paper on the Establishment of Bamboo Plantations at the 15th Commonwealth Forestry Conference-1997 at Zimbabwe.

20. 18. During the post doctoral work, I have published more than sixty research papers related to plantation bamboo and six books are published. One of the book won the BEST BOOK AWARD of the year 2002 in the field of Agriculture by the Government of Tamil Nadu.

21. The Council of Scientific and Industrial Research, NewDelhi awarded both the Senior Research Fellwoship and the Reseaech Associateship for my work on Plantation Bamboo.

22. 20. The Tamil Nadu State Council of Science and Technology (An autonomous body under Government of Tamil Nadu honoured with the TAMIL NADU SCIENTIST AWARD in the year 2001 for the contribution in the field of Plantation Bamboo.

SIGNIFICANT CONTRIBUTION TO PLANTATION BAMBOO (BAMBUSA BAMBOS (L) VOSS).

Bamboo is the vernacular term for members belonging to the subfamily *Bambusoideae* of family *Poaceae*, including all the grasses. Two important characters which make (majority of) bamboo distinct from other grasses are: (i) woody perennial habit and (ii) peculiar flowering and seeding behavior. Most of the bamboos flower and seed at the end of very long vegetative period. Almost all of the 75 genera and 1250 species of bamboo are woody and fast growing (Sharma, 1980). They range from the size of grass to 40 m tall and 30 cm diameter.

Bamboos have versatile uses, as building material, paper pulp resource, scaffoldings, food during normal times in famine and seasonal scarcity, agricultural implements, fishing rods, weaving material, parquet manufacture and as water conduits. It has an important industrial role in paper pulp manufacture, especially in China and India. The new uses of bamboo include stabilizing of soils, substitute for rattan, plywood and particleboard manufacture. Bamboos are becoming increasingly popular in the horticultural industry as a house plant (INBAR Activity Report, 1997). Its plethora of essential uses led to the use of terms such as "green gold", "poor man's timber", "bamboo friend of the people" and "Cradle to coffin timber".

One third of the human race at least uses bamboos for several purposes. The importance of bamboo to the lives of rural people in the developing countries has neither been adequately assessed nor quantified. The bulk of bamboo is harvested either from the wild or rural environment. Approximately 20 million tonnes of bamboo is harvested annually, of which 80 percent is used locally; hence reliable statistics of bamboo use are difficult to collect. Estimates of the total global revenue from bamboo and its products fall around US $ 4,500,000,000

(Liese, 1988). Its accurate trade statistics are difficult to determine as bamboo is usually lumped with other furniture and matting materials. For example, trade statistics often categorize bamboo products under "plaiting materials", which includes materials such as raffia, narrow leaves, willow and straw.

Despite the steadily increasing demand for bamboo little attention has been paid to it in the national forest inventories carried out in Asia, resulting in a serious lack of information on the available and potential supply of bamboos from natural forests. The bamboo resources of tropical forests are spread over evergreen and moist deciduous forest types. Most areas are inaccessible owing to undulating terrain. Hence estimating the actual areas of bamboo for resource evaluation is a herculean task if we adopt conventional field survey methods. (INBAR, Technical Report No-11). An International meeting of experts on Inventory Techniques of Assessment of Rattan and Bamboo in Tropical Forests (jointly organized and sponsored by INBAR, ODA-UK/OFI Oxford, FRIM, Malaysia) was convened in 1995 to discuss ideas on suitable inventory techniques and exchange information on recent surveys and inventories relevant to bamboo in different countries. It is recommended that the potential use of remote sensing data in the form of satellite data products and large scale aerial photographs are highly promising for the inventory of bamboo in natural forests.

The remote sensing data revealed that bamboo forests cover about 14 million hectares of the earth surface with 80 percent in Asia. They are fairly well distributed in all the continents except Europe. All other tropical and subtropical regions of the world are endowed with a rich vegetation of bamboos (INBAR Activity Report 1997).

Bamboo is a cultural feature of south and Southeast Asia. No country in the region is without an indigenous bamboo flora. India is one of the leading countries of the World, next to China in bamboo production with 32, 30,000 tones per year (Pathak, 1989). India shelters

about 130 species occurring over an area of 10.03 million ha. This constitutes about 12.8 per cent of the total forest area of the country. They form an important constituent of the deciduous and evergreen forests and spread over tropical and temperate regions, extending from alluvial plains to high mountains, ascending to altitudes of 4000 m in above mean sea level. Bamboos are found as an under story in the forests of most states except Kashmir valley. They form rich belts of vegetation in well-drained parts of tropical and subtropical habitats and rise up to 7000 m of altitude in the Himalayas (Vermah and Bahadur, 1997).

Sustainable resource management has, so far, not been possible mainly because of insufficient knowledge, skills and practices in both indigenous and scientific management systems. For bamboos, improved techniques are needed for the sustainable management of natural forests (INBAR Activity Report 1995).

Over-exploitation associated with growing human populations, gregarious flowering, destruction of tropical forests and new demands on the resources for industrial use, especially by the pulp and paper industry, have resulted in wide-scale decimation of bamboo stocks; from vast forests of bamboo in South and Southeast Asia at the beginning of the century, we are left with the current situation of acute scarcity. Many countries have been forced to severely restrict and in some cases even ban out right the harvesting and exporting of bamboos from natural forests.

However, demand for bamboo is increasing much more than their availability. In the near future, a major shortfall in the availability of bamboo raw material for the paper industry is expected (Adkoli, 1990). Due to severe deforestation and the present limitation of bamboo propagation and improvement, it is unlikely that the increasing demand will be fulfilled. This emphasizes the need for enhancing bamboo production. This can be achieved by (i) increasing the area under bamboo

cultivation. (ii) selective multiplication of better clones and (iii) use of improved varieties. Bamboos need to be given more importance in agroforestry, social forestry and wasteland development (Shanmughavel, 1995).

The report on the National Commission on Agriculture (1995) brought out some figures about the current demand and output of the projected bamboo requirements for 2000 (7,005 million Cu. m) and 2005 (9,820 million Cu. m) and recommended the measures required to bridge the increasing gap between demand and supply. It was recognized that raising elaborate bamboo plantations and also using the existing natural bamboos judiciously and efficiently could only sustain the availability of bamboo resources. Systematic cultivation of bamboos and their scientific management can therefore, ensure sustainable production.

Efforts are therefore, directed towards the cultural and agronomic techniques which will boost bamboo production so that raw material in sufficient quantity can be made available to farmers, rural households and industries. However, very little is known about several aspects of this fascinating plant and these are receiving a high priority in the research activities of bamboo specialists. Thus bamboo biology, embryology, cytology, physiology of flowering, ecology, silviculture and utilization are all under detailed investigation. Even the authentic identification of the different species of bamboos, which is basic to all studies, has to be undertaken with a sense of purpose.

Research on Bamboo has increased rapidly recently. Activities were strengthened by the creation of an IUFRO (International Union for Forestry Research Organization) project group on bamboo in 1976. This was followed by an IDRC (International Development Research Council) – IUFRO workshop in Singapore, 1980, a subsequent conference at the IUFRO Congress in Kyoto, 1981 and an International Workshop in Hangzhosuw 1985, organized by the Chinese Academy of Forestry and IDRC in cooperation with IUFRO 1986). A third international bamboo

workshop was held at Cochin, India in 1988, organized by Kerala Forest Research Institute (KFRI) and IDRC, the fourth was at Chiengmai, Thailand in 1991 and the fifth was at Udubi, Bali, Indonesia in 1995 and the sixth was at Costa Rica in 1998. Recently seventh World Bamboo Congress held at New Delhi, India in March 2004. These efforts are already bearing fruit.

Literature on the dynamics and productivity of plantation stands are almost non-existent. The productivity of bamboos on unit area basis (t/ha) in plantations is almost meager in India.

The importance of physical properties of soil for tree growth has been stressed (Auten, 1945). Foliar analysis is accepted as a more reliable mean than chemical soil testing for determining the nutrient needs of the trees and nutrient availability levels in the soil (Heiberg and White, 1950). There are known sources of variations, which need to be considered in relation to the availability of the nutrients, the age of the stands and influence of the environmental factors (Pande *et al.,* 1989). Hence the study on nutrient distribution in biomass components of various trees is essential which is meager in relation to plantation bamboos.

Circulation of nutrients also plays a very important role in forest plantation ecosystems. Nutrients are circulated relatively large amounts within the ecosystems. Much of the nutrient uptake by trees is returned to the soil by way of litter fall, but an appreciable amount is retained by the bole, bark and branches which are usually harvested and removed from the site (George, 1977). This loss of nutrient is greater with intensive utilization of fast growing species. The study on biological productivity and cycling of nutrients becomes therefore necessary with a view to maximize the productivity from limited forest areas (Pande *et al.*, 1989). The recycled nutrient from decomposing forest litter is one of the main sources for maintaining the growth of forest tree. Although studies have been carried out on the litter production and its

decomposition in tropical and temperate forests (Bray and Gorham, 1964; Staaf and Berg, 1981) the required information on plantation bamboo is limited (Fu Maoyi *et al.*, 1988).

During the last few decades, bamboo has become a major source of raw material for the Indian pulp and paper Industry. During harvesting bamboo from natural forest, no definite age for cutting is maintained, so bamboos of different age groups were harvested indiscriminately. As a result pulping of bamboos of different age groups may results in heterogeneous cooking, and inferior pulp quality (Bose *et al.*, 1988). To overcome these problems, researches were conducted to determine the optimum age for felling of plantation bamboo for pulp yield and quality.

In view of its multi-dimensional importance in various spheres, a thorough understanding of several factors related to bamboo growth, productivity, (biomass), anatomy, litter production, nutrient cycling and pulp and paper characters of the plantation bamboo has become necessary.

In such a condition of bamboo research, I have chosen the topic "*Plantation Bamboo*" for my doctoral research. An experimental trial of *Bambusa bambos* was conducted at Kallipatty, near Sathyamangalam, Tamil Nadu State, India. "Studies on organic productivity, nutrient distribution, nutrient cycling, pulp and paper characteristics of plantation bamboo [*Bambusa bambos* (L) Voss]" up to the age of six years formed the basis for doctoral research.

After my doctoral research, researches in the plantation bamboo was continued to record its further growth, recruitment of culms, organic productivity nutrient distribution, nutrient dynamics and pulp characters up to 10 years.

For a vivid knowledge of the bamboo crop, growth studies were carried out by determining the number of culms/clump from different

age groups, measuring their height and diameter at breast height (DBH) and assessing monthly recruitment of culms. The allocation of above-ground biomass in growing *Bambusa bambos* revealed that 85% was to the culm 10-15 to the branch and only 1% to the leaves. The organic productivity of six different age groups of *Bambusa bambos* was investigated. Each age group annual biomass production, mean periodic production and net primary productivity was estimated. It was observed that, the grand total biomass (t/ha^{-1}) increased by 5.4 times form 1st (2.29) to 2nd year (12.51) by 4.1 times to 3rd year (52.47) by 2.4 to 4th year (127.82) by 1.8 times to 5th year (234.3) and 1.2 times to 6th year (297.8). From 7th year, a decline in the grand total biomass was recorded and published (Papers 1-15, Book 1&2).

The entire biomass productivity depends ultimately on the photosynthetic efficiency of the leaf. Therefore leaf anatomy, estimation of photosynthetic pigments, total protein, starch and carbohydrate were made on 1 to 6 years old bamboo leaves. The leaf which has a krantz anatomy, typical of a tropical grass and its biochemical characters are inversely proportional with age (Paper 16).

In order to obviate, the felling of standing green trees on the new site, where the biomass estimates were required, and regression equation was applied. The data obtained were fitted to the prediction equations. Both linear and multiple regression models were tried. On the basis of coefficient of determination the most suitable prediction equation was selected (Papers 6 and 7). A standardization of cultural practices of *Bambusa bambos* has been suggested (Book 2).

The peak concentration of all nutrients (N, P, K, Ca and Mg) was observed at the bud stage of leaves, branch and culm (Paper 7). The percentage distribution of nutrients in different biomass components varied. Leaves contained 33-37% N, 3-4%P, 33-35%K, 10-16% Ca and 13-17% Mg. Branches contained 31-37%N, 3-4% P, 33-36% K, 12-16% Ca and 17-19 % Mg. On unit area basis (kg/ha), the maximum amount of all

nutrients was found in culm followed by branch, rhizome and leaves (Papers 17-25, Book 2).

The litter fall in the *Bambusa bambos* indicated a bi-model pattern with the principal peak in November (776 kg/ha) and another in April (619 kg/ha). Total leaf litter was 11833 kg/ha and twig litter was 8473 kg/ha. The annual production was thus 20306 kg/ha/yr. The nutrient return through annual litter fall on unit are basis (kg / ha) indicated that 184N, 16P, 183 K, 91 Ca and 96 Mg are returned to the soil (Paper 25, Book 2).

Based on the above, nutrient cycling in the plantation on an annual basis was determined. A complete harvest of above ground biomass of *Bambusa bambos* at the age of 6 years will deplete (kg ha^{-1}), 2387 N, 234 P, 2559 K, 1188 Ca and 1330 Mg. Rhizome and leaves when left in the field, the nutrient loss is reduced by 5%. The results of the present study revealed that, the importance of application of fertilizers after harvest of biomass components of *Bambusa bambos* with reference to nutrient uptake and cycling (Book 2).

The total pulp yield increases with culm age of the (36.36% to 48.80%). The pulp required only 8.91% to 10.49% chlorine for bleaching to develop brightness between 75% and 84%. The physical strength of bleached and unbleached pulp also increases with age up to 6 years, and then decreased (Papers 26-32, Book 2). The study revealed that in *Bambusa bambos* although no appreciable change in the chemical composition of pulps could be detected with increasing age, it seems that the bamboo species reached maturity during the first year of growth. Hence 1 – 10 year old culms can be used as a raw material for pulping. However in order to get a higher annual yield of culms in the subsequent years, it is recommenced that a 36-month cutting cycle is ideal for pulping purposes (Paper 28, Book 1 & 2).

Further nutrient dynamics (balance and turnover of nutrients) (Paper 21), effect of fertilization on the growth and productivity of the

plantation bamboo (Paper 33), studies on seed storage (Paper 34), vegetative propagation (Paper 35), harvesting methods (Paper 36) has also been investigated.

Comparison of pulp and paper making characters with some tree species was also studied with the aim to investigate the nature of pulp qualities of bamboo over tree species (Paper 27, Book 2). To study the growth of the transplanted *Bambusa bambos* seedlings in the natural forests, a trial was conducted at Sathyamangalam reserve forest area, Tamil Nadu, India (Paper 37 and 38, Book 1 & 2) To evaluate the performances of the growth of bamboo plantations raised using *in vitro* seedlings in different parts of Tamil Nadu have also been done (Book 2). The efficient utilization of plantation bamboo (Book 1 & 2), the need for raising bamboo plantations (Papers 31, Book 1) problems and prospects of raising bamboo plantations (Paper 39, Book 1) are also suggested. *Bambusa bambos* for community forestry programme (Papers 40, Book 1), and regeneration of forest tree species including *Bambusa bambos* (Paper 41), effect of fire on *Bambusa bambos* (Paper 42) and a case study of traditional bamboo workers in Sathyamangalam (Paper 43) were also investigated.

The intercropping of agricultural crop and its growth, yield and land equivalent ratio of pigeon pea (*Cajanus cajan*) (Paper 44), soybean (*Glycine max*) (Paper 45), turmeric (*Curcuma longa*) (Paper 46) and ginger (*Zingiber officinale*) (Paper 47) with bamboo (*Bambusa bambos*) plantations were tried (Agroforestry study). The aim of this study is to identify the suitable agricultural crops, which can be recommended for intercropping during initial stages of raising bamboo plantation (Paper 48).The interaction between agricultural crops and plantation bamboo, its productivity, land equivalent ratio and nutrient cycling in agro forestry systems were also investigated.

In the entire agrisilvicultural model, on an average of three replicates, the per plant yield of pure agriculture crops was found to be higher, when compared with intercropped stand. The production of new culms/clump in the intercropped bamboo stand found minimum as compared with pure bamboo stand (Paper 51). The land equivalent ratio of bamboo producing culms (dry weight) with agricultural crops showed 1.2 in the bamboo/ pigeon pea, and bamboo/ soybean model, however 1.1 in the bamboo/ turmeric, and bamboo / ginger model. This meant that the productivity of one hectare under intercropping is equivalent to that of 1.2 hectares or 1.1 hectares under the sole systems. The results of study revealed that, pigeon pea and soybean appears to provide most benefit to farmers in terms of productivity (Papers 49 to 52).

Further an attempt has been made to assess the growth performance and economic returns of *Leucaena leucocephala* in agroforestry system (Paper 53). Two models for the concurrent production of agricultural, horticultural and forest crops were also investigated. *Moringa oleifera, Casuarina equisetifolia, and Zea mays* (Model A), *Moringa oleifera, Acacia auriculiformis and Zea mays* (Model B). The yield and economic returns from the models are discussed (Paper 54).

A review on the preservation of bamboo and the advantages and disadvantages of different methods of treatments was published on disc, by the Eco-Forestry forum, Kembe, West New Britain Province (Paper 55 & 56). Young bamboo shoots are delicious, eaten as a vegetable. The chemical composition and edible nature of *Bambusa bambos* was evaluated (Paper 57). To popularize the growing of researches for the benefit of public, articles and book (Book 3) are published on regional language from time to time (Paper 58 to 63).

Current researches include developing database models for industry plantations (Paper 64) digitization and automation of the data on tropical forests (Paper 65) and forest informatics.

The Commonwealth Forestry Association (CFA) of the Oxford Forestry Institute (OFI), Oxford, UK, has appreciated my contributions for the development of "Plantation bamboo" researches. They sponsored me to present my paper on the "Establishment and Management of Bamboo Plantations" in the 15th Commonwealth Forestry Conference-1997 at Victoria Falls, Zimbabwe,

The paper on "Plantation Bamboo for Sustainable Productivity" (XI World Forestry Conference Antalya Turkey –1997), "Introduction of Bamboo in Social Forestry", "Methodology to Evaluate Productivity and Nutrient Dynamics in Plantation Bamboo", and "Studies on Growth and Development of Culms In Plantation Bamboo" (VI, International Bamboo congress, Costa-Rica, -1998), " Evaluation of bamboo plantations raised from *in vitro* Plants in Tamil Nadu", India (X Bangladesh Botanical Conference, Dhaka-1999), "Intercropping Trials in Bamboo" and Biomass Production in Bamboo Plantations" (IUFRO World Congress, Kuala Lumpur, Malaysia –2000) have been accepted for oral presentation and the abstracts are published.

ADDITIONAL PAPERS

The thesis is mainly based on the theme *'Plantation Bamboo'* (Productivity –biomass, nutrient cycling, pulp and paper characters and intercropping in bamboo plantations). The relevant work on biomass and nutrient cycling of other forest plantations were also investigated during the post doctoral research and is also included in the thesis (66 to 70).

PAPERS PUBLISHED IN COLLABORATION WITH THE XISHUANGBANNA TROPICAL BOTANICAL GARDEN, THE CHINESE ACADEMY OF SCIENCES, KUNMING, SOUTH WEST CHINA.

The Chinese Academy of Sciences has invited as Visiting Scientist for the collaborative research with the Department of Forest Ecology, Xishuangbanna Tropical Botanical Garden, Kunming, South West China to investigate the natural bamboo survey, Biomass production and Nutrient cycling of a Tropical Seasonal Rain forests in Xishuangbanna, South West China during the year 1999, 2000 and 2001. As a result of collaborative work research papers are published (Papers 71 to 74 which are mostly connected to the main theme of the thesis –Biomass and Nutrient cycling

BOOKS PUBLISHED

Based on my research experience in the field of plantation bamboo, I have published the following books:

1. **Plantation Bamboo** (1997) by Dr. P. Shanmughavel, Dr. K. Francis, Research Supervisor, Dr. M. George, Scientist SD (Co-guide) of the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore are co-authors. International Book Distributors, Dehra Dun.
2. **Physiology of Bamboo** (2001) Dr. P. Shanmughavel, and Dr. K. Francis. Scientific Publishers, Jodhpur.
3. **"Velanmayil Mungil"** (Bamboo in agriculture) (2001) Dr. P. Shanmughavel. Dharani Publishers, Sathyamangalam, India. For the benefit of common people, a book on regional language is also published which won the Best Book Award (2002) in the field of Agriculture by the Govt. of Tamil Nadu.
4. **Recent advances in bamboo research** (edited) (2001) Dr. P. Shanmughavel (Editor), Dr. S. Peddebiah of Institute of wood Science, Bangalore and Prof. Walter Liese, of Germany are Co-editors. Scientific publishers, Jodhpur, India.

5. **Techniques in Forestry Research** (2001) Dr. P. Shanmughavel Pointer publishers, Jaipur, India. With the experience in the field of forestry research the following book was published which won much reputation.
6. **Tree improvement and Biotechnology** (edited) (2004) Dr. P. Shanmughavel and Fr. Dr. S. Ignacimuthu, sj Pointer publishers, Jaipur, India.

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INTERNATIONAL CONFERENCE

1. **Shanmughavel P.,** and Francis K., (1997) Establishment and Management of Bamboo plantation.

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9. **Shanmughavel, P.** (1997) Bamboo and its applications, National Seminar conducted by Department of Tamil, Bharathiar University, Coimbatore. On 23.10.1997.

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DETAILS OF CONTRIBUTION TO THE SOCIETY FROM THE POST DOCTORAL RESEARCH.

The results and outcome of my researches can be used as follows

1. **Farmers:**

   With the help of standardization of cultural practices farmers can raise the plantation of selected bamboo species particularly in (i) Wastelands (ii) elevated grounds (iii) along the field bunds and on river and canal banks. By raising theses plantations on a large scale they can find market in the nearby basket weaving society, and paper industries.

2. **Forest Departments:**

   The methodology given for raising bamboo plantations can be used by the forest officials for growing bamboo under Community forestry, afforestation, agroforestry and social forestry programmes.

3. **Forest corporations:**

   The bamboo plantations are being raised by the forest corporations on a large scale. The results of my findings are used in the following areas to raise bamboo plantations (a) degraded areas, (b) logged over forest (c) marginal farmland and in agro forestry initiatives.

4. **Handicrafts:**

   A large number of cottage industries like manufacture of tablemats bamboo wares, trays and bamboo board are dependent on bamboos as raw material. They can easily purchase from the nearby bamboo grows and expand their industries.

5. Pulp and paper industries:

At the time of extraction of bamboo from the forests, no definite cutting age is employed. Rather, bamboos of different age groups were extracted indiscriminately. As a result, pulping of a mixture of bamboos of different age groups resulted in heterogonous cooking, producing inferior quality pulp. To over come this, a research was undertaken to determine the optimum age for felling of bamboo for pulp and paper making. If revealed that a 36 month cutting cycle is ideal for pulping purposes.

An alternative raw material for the paper industries is suggested.

6. Regression Equation:

Biomass studies may of interest to the grower to judge the performance of species in terms of total biological production and to assess the nutrient drain by the way of harvesting the species. In order to obviate the difficulty of felling of standing green bamboos on the new site, where the biomass estimation is requires, regression equations are needed. By using this regression equation, if the paper industry contracts a bamboo coupe in any forest areas they can calculate and able to predict the productivity of the bamboo on the basis of easily measurable parameters without felling the green bamboos.

7. Development of Agro forestry models:

Agro forestry means the practice of agriculture and forestry on the same piece of land. A new model "Agri-silvi-Horticulture has been suggested for the benefit of farmers. Further intercropping of cultural crops within the bamboo plantations was suggested for farmers to get revenue during the initial stages of raising bamboo plantations.

8. Publications:

The outcome of bamboo researches has been published both in Tamil and English papers for the benefit of farmers. In addition, a book entitled "Bamboo in Agriculture is published in Tamil for the benefit of farmers.

9. Database Models:

The computer aided database is developed for quick reference source for the benefit of research scholars, forest officials and paper industries involved in cultivation and management of Forest plantations.

10. Future Research:

Bamboo biomass is a alternative source for bio-energy and opportunity to pioneer another industrial usage though gasification to produce electricity is suggested for further research in this field.

TAMIL NADU STATE COUNCIL FOR SCIENCE AND TECHNOLOGY
(Autonomous body under Govt. of Tamil Nadu)
தமிழ்நாடு அறிவியல் தொழில் நுட்ப மாநில மன்றம்

Dr. K. SUBRAMANIAN
Member Secretary

Letter No : TNSCS&T / TANSA / TD /

Date : 23/02/2002

To

Dr. P. Shanmughavel
CSIR Research Associate
Dept. of Botany
Bharathiar University
Coimbatore - 641 046.

Sir / Madam,

I am extremely happy to inform you that you are to be honoured with the Tamilnadu Scientist Award. The award function is scheduled at 4.00 p.m on 28th February 2002 at the Vivekananda Auditorium of the Anna University, Chennai - 600 025. The Hon'ble Minister for Education, Govt. of Tamilnadu is the chief guest and will present the award.

I am pleased to invite you to be present personally on the occasion to receive the award.

With Best wishes,

Yours sincerely

Member Secretary

Directorate of Technical Education Campus, Chennai - 600 025. ✆ : 230 14 28 Fax : 044-2301552
Email : tnscst@md2.vsnl.net.in / tnscst@imsc.ernet.in / Web : www.tnscst.com

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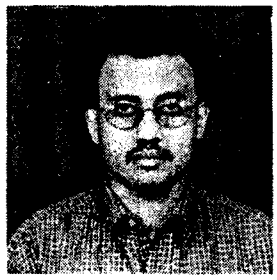

Life Sciences

Dr. B. Shanmughavel was born on 10th May 1964 in Tirunelveli. He earned his B.Sc. and M.Sc. degree in Botany in 1985 and 1987 respectively. He did his M.Phil. in Botany in 1989 and obtained a Ph.D. degree in Botany in 1995. He is working with the Botany Department of Bharathiar University as a CSIR - Research Associate.

Dr. B. Shanmughavel's field of specialisation is plantation bamboo. His interests are in conservation of existing forest resources, forest productivity, nutrient cycling, biomass and bioenergetics and ecosystem analysis. His research findings include work on the reserve forests of Satyamangalam division (Western Ghats) and work on the nutrient distribution in biomass components of bamboo. The results of his findings have given a direction for systematic cultivation of plantation bamboo and their scientific management. His findings on the felling cycle harvesting and post harvest application have been of much use to the paper industry. His work on the economics of bamboo cultivation has benefited farmers. His suggestions on the agro - forestry model of "Agri-Silvi-Horiculture" is an economically and ecologically feasible one.

Dr. B. Shanmughavel has to his credit more than 120 research publications and 3 research level books on plantation bamboo,

(including a book in Tamil). He has also edited an international volume on recent advances of bamboo research. The Oxford Forestry Institute, Oxford U.K. and the Chinese Academy of Sciences, China have invited him for collaborative research.

Dr. Shanmughavel's finding are highly useful for the plantation crop of bamboo for reclamation and economic cultivation. Currently his research involves intereropping in the bamboo plantations. The suggestions arising out of his research are being utilised by the forest officials for sustainable forest management.

Dr. Shanmughavel is a member of the IUFRO Task force on environmental change. He is also reviewer for the Journal of the 'Tropical Forest Science'.

In recognition of his outstanding contribution to sustainable bamboo forest management the Tamilnadu State Council for Science and Technology is privileged to award the Tamilnadu Scientist Award (TANSA) in the field of Life Sciences for the year 2000 to Dr. P. Shanmughavel.

TAMILNADU STATE COUNCIL FOR SCIENCE AND TECHNOLOGY

CHENNAI - 600 025

TAMILNADU SCIENTISTS AWARD

Dr. P. SHANMUGHAVEL *is awarded the* TAMILNADU SCIENTISTS AWARD *for the year 2000 in the discipline of* LIFE SCIENCES *for his work on* SUSTAINABLE BAMBOO FOREST MANAGEMENT.

MEMBER SECRETARY
TAMILNADU STATE COUNCIL FOR
SCIENCE AND TECHNOLOGY

PRESIDENT &
HON'BLE MINISTER FOR EDUCATION
GOVT. OF TAMILNADU

தமிழ் வளர்ச்சித் துறை

சிறந்த நூல்களுக்குப் பரிசு வழங்கும் திட்டம்

பாராட்டிதழ்

தமிழில் 2001 ஆம் ஆண்டில் வெளிவந்து போட்டியில் கலந்து கொண்ட நூல்களுள் வேளாண்மையியல், கால்நடையியல் எனும் வகைப்பாட்டில் வேளாண்மையில் மேங்கில் சிறந்த நூலாகத் தேர்ந்தெடுக்கப்பெற்று நூலாசிரியர் முனைவர். பி. சண்முக வேல் அவர்களுக்குப் பத்தாயிரம் ரூபாய் பரிசுத் தொகையும் இப்பாராட்டிதழும் வழங்கப்பெறுகின்றன.

26/3/2003

தமிழ் வளர்ச்சி இயக்குநர்

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EXPERIENCE CERTIFICATE

This is to certify that

Dr. Piramanayagam Shanmughavel

was invited to the Dept. of Forest Ecology, Xishuangbanna Tropical Botanical Garden from October 1st 1999 to December 1999 for the collaborative research on the following topics:

1. Floristic composition, biomass accumulation of a tropical rain forest of Xishuangbanna.
2. Nutrient cycling of a tropical rain forest of Xishuangabnna SW China.1 Nutrient uptake and retained.

We are very much impressed about his work. His contact and character are good.

Xishuangbanna Tropical Botanical Garden
The Chinese Academy of Sciences

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EXPERIENCE CERTIFICATE

This is to certify that Dr. Piramanayagam Shanmughavel was invited to the Dept. of Forest Ecology, Xishuangbanna Tropical Botanical Garden from November 20th 2000 to January 10th 2001 as visiting Scientist, for the collaborative research on the following topics:

1. **Field survey and data analysis on the soil respiration of local forests.**
2. **Join in the Comparative study on the nutrient dynamics in local secondary forests and shifting cultivation lands.**

We are very much impressed about his work. His contact and character are good.

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CERTIFICATE

This is to certify that Dr. Piramanayagam Shanmughavel from Department of Botany, Bharathiar University had been working cooperatively with scientists of Xishuangbanna Tropical Botanical Garden (XTBG), the Chinese Academy of Sciences (CAS) from July 31 to August 27, 2001. His work at XTBG, CAS includes the soil and root respiration in local forests.

We appreciate the impressive work he conducted here with us.

CAO Min

Professor in Plant Ecology

Deputy Director

Xishuangbanna Tropical Botanical Garden

The Chinese Academy of Sciences

Sep. 5th, 2001

PLANTATION BAMBOO

Dr. P. Shanmughavel
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FOREWORD

Forests, the gift of Nature yield innumerable forest products which command a high demand. At present due to indiscriminate destruction of forests, the demand is not adequately met by the natural resources. The fiber products derived from bamboo is such an example. With the dwindling of natural bamboo, quality rayon, paper and other fibre product industries are left with only alternative methods of cultivation. The National Commission on Agriculture recommends to bridge the gap between the demand and supply by recognizing the systematic cultivation of bamboo and their scientific management to ensure sustainable production. In the absence of natural bamboo vegetation, the current plantation technique is conventional with little scientific background. Many plant species designated as agriculture crops have been documented with monographs. However cultivation of bamboo as a plantation crop dealing with the establishment and management of plantation, growth and development, fertilizer application, felling cycle, yield, introduction of social forestry etc., are not documented as a monograph on bamboo which need is fulfilled through this publication. The work of the authors in bringing such a publication deserves appreciation. This no doubt will be a useful guide for farmers and forest research institutions who would be concerned with the fiber products.

(S. Subramanyan)

PREFACE

Bamboos are giant, woody, tree-like grasses with a long history as an exceptionally versatile and widely used resource. Over 75 genera and 1,250 species have been identified. Bamboo is a cultural feature of south and southeast Asia. No country in the region is without an indigenous bamboo flora. Its plethora of essential uses has led to the use of terms such as the "poor man's timber", the "Cradle to coffin plant", "green - gold", "bamboo friend of the people" and it still provides the material needed for existence. Yet over - exploitation associated with growing human populations, destruction of tropical forests and new demands on the resources for industrial uses, especially by the pulp and paper industry, has resulted in wide scale decimation of bamboo stocks. Compared with the vast forest of bamboo found in south and southeast Asia at the beginning of this century, we are left with the current situation of acute scarcity. Efforts are therefore underway to research into cultural and agronomic techniques which will boost bamboo production so that raw material in sufficient quantity can be made available to farmers, rural households and large industries.

The present crisis in sustained availability can be ensured only by raising extensive bamboo plantations. The present plantation techniques is based on experience rather than on scientific basis. Species which have attained a crop status in agriculture have long decades of directed endeavour behind them. Bamboo has not attained a similar status due to lack of sustained investigations. The need for an authentic but comprehensive and a broad based book on plantation bamboo has been long felt. Therefore, all available data is documented in a scientific manner for use as reference to farmers, foresters as well as bamboo researches. This publication is an effort in that direction.

We hope that this book will serve as a good reference, for those interested in the subject and will help them to understand more fully, and possibly also to solve, the problems posed in the cultivation and management of plantation bamboo.

- Authors.

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CHAPTER - 1

INTRODUCTION

By far the single most important item of forest produce used by rural communities of the tropics, from the cradle to the coffin, is the bamboo. Bamboo is a member of the grass family (Poaceae). Two important characters which make (majority of) bamboo distinct from other grasses are : (i) Woody perennial habit and (ii) peculiar flowering and seeding behaviour. Most woody bamboos flower and seed at the end of very long periods of vegetative growth. Over 75 genera and 1250 species are reported to occur in the world. India has perhaps the world's richest resources of bamboos, having about 130 species occurring over an area of 10.03 million ha. This is about 12.8 per cent of the total forest area of the country and represent 20 per cent of India's total production (Shanmughavel, 1995).

And yet, over exploitation associated with growing human populations, gregarious flowering, destruction of tropical forests and new demands on the resource for industrial uses, especially by the pulp and paper industry, have resulted in wide-scale-decimation of bamboo stocks; from vasts forests of bamboo in South and Southeast Asia at the beginning of this century, we are left with the current situation of acute scarcity. Many countries have been forced to severely restrict and in some cases even ban outright the harvesting and exporting of bamboos.

The report on the National commission on Agriculture brought out some figures about the current demand and output of the projected bamboo requirements for 1980 (4.274 million Cu M) and 2000 (7.005 million

Cu M) and recommended the measures required to bridge the increasing gap between demand and supply (Adkoli, 1992). It was recognised that the availability of bamboo can only be sustained by raising elaborate bamboo resources and also using of existing natural bamboos judiciously and efficiently. Systematic cultivation of bamboos and their scientific management can therefore, ensure sustainable production.

However, we know very little about several aspects of this fascinating plant and these are receiving a high priority in the research activities of bamboo specialists. Thus its biology, embryology, cytology, physiology of flowering, ecology, silviculture and utilisation are all under detailed investigation. Even the authentic identification of the different species of bamboos which is basic to all other studies has to be undertaken with a sense of purpose.

Research has increased rapidly in recent years. The growth pattern and productivity of different bamboo species has been studied by several workers (Deogun, 1937; Kadambi, 1949; Gupta, 1952; Krishnasamy, 1952; Seth, 1954; Hubermann, 1959; Banik, 1988; Othman, 1992; Shanmughavel and Francis, 1993a and Shanmughavel, 1995). Activities were strengthened by the creation of a IUFRO project group on Bamboo in 1976. This was followed by an IDRC - IUFRO workshop in Singapore, 1980 (IDRC, 1980) a subsequent conference at the IUFRO congress in Kyoto 1981 (Higuchi, 1981) and an International workshop in Hangzhosuw 1985. organised by the Chinese Academy of Forestry and IDRC in co-operation with IUFRO (IDRC, 1986). A third international Bamboo workshop was held in Cochin India in 1988, organised by KFRI and IDRC, the fourth was in Chiengmai.

Thailand in 1991 and the fifth was in Ubudi, Bali, Indonesia in 1995. These efforts are already bearing fruit.

The demand for bamboo is increasing much more than their availability. In the near future, a major shortfall in the availability of bamboo raw material for the paper industry is expected (Anonymous, 1990). Due to severe deforestation and the present limitation of bamboo propagation and improvement, it is unlikely that the increasing demand will be fulfilled. This emphasizes the need for enhancing bamboo production. This can be achieved by (i) increasing the area under bamboo cultivation, (ii) selective multiplication of better clones and (iii) use of improved varieties. Bamboo needs to be given more importance in agro-forestry. social forestry and wasteland development. Rural economics in Southeast Asian countries are dependent on biomass production and popularization of bamboo cultivation and bamboo based industries would greatly help in rural development (John *et al.*, 1994).

The present bamboo plantation technique is based on experience rather than on scientific basis. Species which have attained a crop status in agriculture have decades of directed endeavor behind them. Bamboos have not attained the same status due to lack of sustained investigations. A few problems of fundamental and applied nature, which need to be tackled immediately regarding bamboo farming. This book focuses the importance of raising bamboo plantation, establishment and management, yield and economics, felling cycle, fertilizer application and also discusses the problems and prospects of plantation bamboo.

CHAPTER - 2

DISTRIBUTION

Bamboo is a woody grass with multiple utility and usually forms a rich belt of vegetation in moist deciduous, semi-evergreen, tropical, sub-tropical and temperate forests. About 14 million hectares of the earth surface is covered by bamboo forests with 80 per cent in Asia. They are fairly well represented in all the continents except Europe. All other tropical and subtropical regions of the world are endowed with a rich vegetation of bamboos.

India is one of the leading countries of the world, second to China in bamboo production with 32,30,000 tonnes per year (Pathak, 1989). India shelters a large number of bamboo species and is considered as one of the largest reserves of bamboo in the world. There are 130 indigenous and exotic species of bamboos falling under 75 genera in an area of 10.03 million hectares. This constitutes around 12.8 per cent of the total area of forest cover in the country. They form an important constituent of the deciduous and evergreen forests and are spread from tropical to temperate regions, extending from alluvial plains to high mountains, ascending to altitudes of 4000 in above mean sea level. Bamboos are found as an understorey in the forests of almost all the states except in Kashmir valley. They form rich belts of vegetation in well-drained parts of tropical and sub-tropical habitats and rise upto 7000 m of altitude in the Himalaya (Varmah and Bahadur, 1980).

Since bioclimatically, India is divided into five major regions viz., the alpine, sub-tropical, tropical moist and dry tropical regions, the distribution of bamboos also

differs from one region to another with certain bamboo taxa characteristic of a particular zone. The principal bamboo genera occurring in India are : *Arundinaria, Bambusa, Chimonobambusa, Dendrocalamus, Dinochloa, Gigantochloa, Indocalamus, Oclandra, Oxytenenthera, Phyllostachys, Indocalamus, Dendrocalamus, Dinochola, Schizostachyum, Semi arundinaria, Sino bambusa*, etc., More than 50 per cent of these occur in Eastern India - Arunachal Pradesh, Assam, Manipur, Maghalaya, Mizoram, Nagaland, Sikkam, Tripura and West Bengal. Other areas rich in bamboo are the Andamans, Madhya Pradesh and Western Ghats.

Of all the commonly occurring genera of bamboos, the genus *Bambusa* is the widely distributed one in India. *Bambusa bambos* occurs either wild or cultivated throughout the plains and low hills of India from other Southern tip of the peninsular region to the lower Himalayan region. The next widely distributed genus is *Dendrocalamus*. It occurs in the plains of South and central India and the dry hills of North India. From East to West it occurs from Punjab to Assam and other North-eastern states. *Bambusa, Oxytenanthera* and *Dinochloa* are the widely represented genera in the Andamans and Nicobar islands (Figure - 1). Other principal genera of India like *Arundinaria, Indocalamus, Oxytenanthera, Schizostachyum* and *Melocanna* are concentrated in the Western Ghats and in the North-eastern region. The genera *Schizostachyum, Phyllostachys* and *Gigantochloa* are widely distributed in the North-Eastern India.

The main bamboos of Tamil Nadu are *Bambusa bambos* and *Dendrocalamus strictus*. The former occurs in moist valleys, while the later in the drier slopes. *Dendrocalamus strictus* (or) Male bamboo is the species

commonly, found in bamboo tracts in Tamil Nadu upto 1000 meters elevation. Other species found are *Bambusa tulda, Oxytenanthera nigrociliata, Cephalostachyum pergracile.* In the Western Ghats and on coasts where mostly evergreen and semi-evergreen forests occur 5 species of *Oxytenanthera* and 8 species of *Ochlandra* are met with; on the higher hills of Nilgiris and Pulneys, species of *Arundinacea sensulato* occur. Bamboos are found in the Western Ghats, Sherveroys and Javadis of Tamil Nadu. In Western Ghats, *Dendrocalamus strictus* and *Bambusa bambos* are found in Bolampatty, Pollachi, Udumalpet and Thoonakadavu range of Coimbatore division, Coonoor and Mudumalai ranges of Nilgiris division. *Dendrocalamus strictus* is widely distributed in Salem, Attur, North and south Sherveroys ranges of Salem division and Thuraiyur range of Trichy division.

In Javadis, the *Dendrocalamus strictus*, is distributed over Chengam, Tirupattur, Alangayam, Sathanoor, Karur and Polur ranges of Vellore circle. In addition to natural distribution of bamboo, plantation bamboo has been raised in Salem, Kalrayans, Hosur and "Padugai" areas on the banks of River Cauvery in Thanjavur and Trichy districts over 12000 ha. The area under private bamboo plantation in Tamil Nadu is estimated to be 1942 ha forests of Tamil Nadu with rainfall ranging from 750 mm to 2600 mm per annum (Balaji, 1992).

Bamboo Supply and Demand

The estimated forest area under bamboos in India (including plantations) is nearly 10 million hectares which is about one seventh of the total forest area of the country. Table - 1 shows the bamboo bearing areas and potential annual production in different states. As against

the potential availability of about 4.6 million tonnes of bamboo in the country, the out-turn of bamboo in different states and Union Territories during 1984 - 85 as reported in India's Forests 1987 is shown in Table 2. The annual out-turn of bamboo usually fluctuates within a wide margin, largely because bamboo flowers gregariously and such crop has to be harvested during the year. Consequently in certain years, in some states the out-turn may exceed the potential production. It is evident that there is a wide gap in the estimated potential exists in the states of Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Tripura and Bastar districts of Madhya Pradesh (Tewari, 1981).

Before inception of a paper mill in Tamil Nadu, bamboo was mainly used for construction, cottage industries and for agricultural purposes. There were different commercial classifications. For example, Bambusa bambos (Peru moonkil) used to be classified as 'Thattai', 'Madura Pootu', 'Guranai', 'Dokku', 'Rasi poottu' and 'Thappai' in Periyar District. While the first three are long and thick and are used for constructional purposes, 'Rasipoottu' is used as support for plantation crops and for fencing. Once paper mill was started establishing in sixties, it turned out to be a major consumer of bamboo. Bamboo supply was around 50,000 tonnes until mid-servanties will show gradual reduction in the supply of bamboos from over 50,000 tonnes to around 10,000 tonnes now. While the Bamboo supply is declining on one hand, the supply of Eucalyptus pulpwood has been steadily increasing in Tamil Nadu over the same period (Figure - 2).

The reasons for the reduction in supply of bamboo are many. Over exploitation, failure of regeneration after gregarious flowering, drought, fire and over grazing have made serious in roads into the growing stock of

bamboos. The shift in policy from exploitation to comprehensive conservation of forests during eighties is another important reason for continuing the rest given to bamboo areas and consequent reduction in supply. Reduction in supply of bamboos has not adversely affected the paper mills as the industries managed to compensate the shortfall in bamboo by making use of increased availability of Eucalyptus and other hardwoods as well as bagassy from sugar mills. Infact, one of the major paper mills in Tamil Nadu (viz.) Tamil Nadu Newsprint Limited, with an installed capacity of 90,000 MT of paper per year, uses mainly bagassy supplemented with 80,000 tonnes of Eucalyptus wood. The projected demand of bamboo in Seshasayee Paper and Board Limited is in allotment of 10,000 to 15,000 tonnes per annum at present. For efficient manufacture of paper, this mill requires a minimum quantity of bamboo to the tune of 20% of their total raw material requirement. With the possible establishment of another paper mill in this state and taking into account the requirement of bamboo for construction, agricultural purpose and cottage industries, the estimated demand for bamboo in Tamil Nadu will be around 1,00,000 tonnes by 2,000 AD (Balaji, 1992).

In order to meet anticipated increase in demand and also to restore bamboo cover for ecological reasons, Forest Departments have taken up restoration of bamboo as one of the objectives under different schemes. Many of the over worked bamboo areas in Tamil Nadu have been given rest for recuperation. In fact some of the bamboo areas that were given rest have recovered exceedingly well; Varattupallam slopes in Erode division and Gundri areas of Sathyamangalam division bear testimony to this fact. Restoration of bamboo has been taken up under Western Ghats Development Programme, Hill Areas Development

Programme and Nilgiris Biosphere scheme. Tamil Nadu has also developed 12,000 ha of man made bamboo plantations. Improved soil and moisture conservation measures and provision of suitable fencing are two important aspects of bamboo restoration. Elephant proof trenches and electric fencing are being tried to keep the cattle and wild life damage to minimum.

Gregarious flowering of bamboo had been noticed in different parts of Tamil Nadu during different periods. Gregareous flowering was noticed in bamboo forests of Pollachi during 1958 - 59; in Sherveroys during 1967; in Sathyamangalam during 1972 - 73 and in parts of Javadis during 1975 - 76. Recently bamboo has flowered in Vellore division. Flowered and dry bamboo is being supplied to M/S Seshasayee Paper and Board limited during 1990 - 91. Dendrocalamus strictus flowers between 30 to 50 years of age. Bamboo seeds profusely and is capable of natural regeneration provided fire and grazing are kept at minimum. The seeds are viable for few months only. Hence, failure of monsoon followed by prolonged drought, recurring forest fires and over grazing by cattle had greatly impeded the process of natural regeneration in the past. Harvesting of bamboos in reserved forests will have to be done diligently. Infact, the felling rules prescribed for bamboo listed below are quite comprehensive.

1) A minimum of 6 matured culms should be left in each clump.

2) No immature culm of less than 1 year age shall be removed.

3) No culm should be removed with rhizome

4) Culms shall be cut clean and cut as low as

possible (30 cms in height)

5) Felling shall be made as far as possible on the side of the clump opposite to that from which the largest number of new culms spring-up.

But on many occasions the felling-rules prescribed were followed more in breach than in practice by the contractors in the past. Hence, Bamboo should be extracted only departmentally under the supervision of technically qualified foresters.

Bamboos are the excellent species to be promoted under social forestry. Bamboo is a promising cash crop which can give return of Rs. 10,000 to 20,000 per acre to the farmer if managed properly (Balaji, 1992). Realising this fact certain enterprising farmers in Thanjavur, South Arcot and Periyar Districts have taken to bamboo farming. A nine year old bamboo plantation over 6 1/2 acres in Thaneer Pandal in Periyar district with once-a-week irrigation, has grown over 28 m in height. Bamboo grows exceedingly well with watering once in a week (or) 10 days. Intercrops like Cholam, Ragi, Groundnut, or Turmeric can be grown with bamboo for the first 2 years.

Bamboos are exceedingly fast growing and extensively useful species with exceptional efficiency to ameliorate the environment. Hence restoration and development of bamboos is not only silviculturally significant but also sociologically relevant.

CHAPTER - 3

TAXONOMY

The importance of bamboos to the national economy as an industrial raw material, besides their more than thousand uses in day to day life, is well known. Bamboos have fascinated scientists and laymen for centuries. To layman all bamboos look alike but there are more than 1250 species described under nearly 75 genera. Bamboo classification is beset with a number of problems and has been tackled from time to time by different authors based on different aspects.

Bamboos and herbaceous bambusoid-grasses are grouped into the sub-family Bambusoideae (or) tribe Bambuseae under the family Gramineae (Poaceae). Most botanists agree to this sub-family (or) tribe position. There are also arguments in favour of conferring an independent family status to this group (Nakai, 1925). Soderstrom and Calderon (1980) are of the opinion that the bamboos and the bambusoid grasses evolved from a common stock. In herbaceous bambusoid grasses botanists have satisfactorily delimited the genera. In bamboos the generic delimitations still remain incomplete (Soderstorm , 1981). In 1913 Camus proposed a modification of Bentham (1883) classification for Bambuseae. Later in 1935 Camus expanded it and suggested seven tribes - Arundinareae, Arthrostylidae, Chusqueae, Bambuseaeverae, Hickelieae, Synandrae and Bacciferae. He divided the tribe Bacciferae into four sub-tribes Dendrocalaminae, Melocanninae, Pseudocoixinae and Perrier bambusinae. In Holttum's (1946) opinion both the systems of classification (Bentham's (1883) modification of Munro (1869)'s and

Camus (1913) do not confirm with the natural order. He stressed the need for a natural system of classification, based on the structure of ovary (Holttum, 1956). According to this system there are four types of ovaries : Schyzostachyum, Oxytenanthera, Bambusa-Dendrocalamus and Arundinaria types.

Grosser and Liese (1973) based on the morphology of vascular bundles (in 52 species belonging to 14 genera) grouped into four categories. According to them, all the species with pachymorph rihzomes come under three basic vascular bundle type. Clayton and Renvoize (1986), classified the sub-family Bambusoideae into thirteen tribes. The herbaceous bambusoid grasses are classified into twelve tribes, which are not sub-divided into sub-tribes. All the woody bamboos are placed under the tribe Bambuseae which is further divided into three sub-tribes : Arundiniae, Bambusinae and Melocanninae. From the above description the need to consider more characters for a better elucidation of inter-relationships between bamboo genera and species are very clear. Among these, characters which divide bamboos into major categories, characters of reproductive structures and characters which are easily observable (in the field) will be of much use. Earlier Munro (1869), Brandis (1899) and Mc Clure (1966) have divided bamboos into major categories on the basis of different characters.

Munro (1869) classified bamboos into three categories; (i) species in general having 3 stamens and 3 lodicules as Triglossae (or) Arundinariiae, (ii) species having 6 stamens and the fruit a caryopsis as Bambusae verae (or) true bearing bamboos. Based on the flowering behaviour, Brandis (1899) classified bamboos into three categories: (i) those which flower annually (ii) those which

flower gregariously and periodically, and (iii) those which flower irregularly. According to Blatter (1929) these three categories are fairly complete and all those species which cannot be grouped under the first and second category will go under the third category. Mc Clure (1966) divided bamboos on the basis of the pattern of rhizome growth into two categories (i) species having sympodial (pachymorph) rhizomes, which are solid, usually short and thick and their lateral buds producing solitary culms (each new culms having its own root system to provide water and nutrients) and (ii) species having monopodial (leptomorph) rhizomes (which are long slender and hollow) continuing horizontal growth until constrained and most of the lateral buds on them giving rise to new culms.

Studies on the reproductive biology in bamboos (Nadgauda *et. al.*, 1980, 1993, John *et al.*, 1995) have shown that there are two major categories; (i) the species in which the androecium and gynoecium mature at the same time as observed in *Bambusa bambos* and (ii) the species in which the gynoecium matures earlier than the androecium as in *Dendrocalamus strictus*. In the first category the "lemma" and "palea" open up and expose the reproductive structures to the pollinating agent (wind). Stigma and anthers remain at two different planes; the filaments being very long and slender, anthers remain at a much lower plane then the stigma. Thus there is a physical barrier to pollination of a stigma by pollen from anthers of the same flower (self-pollination). There can be some seeding during sporadic flowering (in species where there is no self-in-compatibility). In the second category "lemma" and "palea" do not open up but stigma and anthers are exerted at different times, when they mature. There is a gap between the female and male phases (3-4 days (or) more depending on the species). Thus it is a physiological

barrier. In species under this category there may not be seed-set during sporadic flowering and also in gregarious flowering of isolated clumps. John *et al.* (1994) proposed a division of the tribe Bambuseae into two groups : (i) Bambusa type and (ii) Dendrocalamus type. A survey of the literature indicate that the genera *Bambusa, phyllostachys* and *Pseudosaga* belong to the first category and *Dendrocalamus, Melocanna* and *Ochlandra* (Venkatesh, 1984) belong to the second category. When reproductive biology is studied in more and more species and genera (as and when they flower), it would be apparent how they are distributed under these two broad categories.

Both *Bambusa* and *Dendrocalamus* strictus belong to the group *Bambusa verae* (true bambos) (Munro, 1869), gregariously and periodically flowering category (Brandis, 1899), the groups having pachymorph (Sympodial) rhizomes (Mc Clure, 1966). However, John *et al.*, (1994) proposed the system of classification based on the maturing of the reproductive structures. These observation show the importance of studies on reproductive biology in bamboos, for planning breeding strategies as well as for better understanding in their interrelationships.

CHAPTER - 4

ECOLOGICAL REQUIREMENTS

Bamboos have a wide distribution in the country and there is hardly any state where lack them. Their distribution is governed largely by the condition of rainfall, temperature, altitude and soil. In India, bamboo forms rich belts of vegetation in well drained parts of the monsoon region at the foot of the Himalayas and rises upto 7000 metre of altitude. Their distribution is quite dense in the Western Ghats, Bengal, Sikkim, Assam, Arunachal Pradesh and Andamans (Bahadur, 1979).

Climatically bamboo prefers regions of high rainfall ranging from about 1270 mm to about 6350 mm or even more, though they also occur in dry deciduous forests with as low a rainfall as 750 mm. Rainfall plays a very important and dominating role in the distribution and growth of different species. A maximum temperature of 46.70° C and a minimum temperature of 3.30° C are recorded from bamboo bearing localities.

The distribution of various bamboos in areas adjoining the sea coast appears to be governed to a great extent by the relative humidity. It has been observed that the interior dry regions unaffected by the sea breeze are usually occupied by *Dendrocalamus strictus* while those situated near the coast, characterised by relatively high humidity are dominated by *Bambusa bambos.*

Bamboo is a light demander. Under heavy shade thin and whippy culms are produced. However, a certain amount of overhead shade is also necessary during the

early stages of development of bamboo seedlings before they form clumps. There is a direct relationship between the incidence of light and density of clumps, largest number of bamboos is obtained when overwood is clearfelled. Removal of overhead cover is beneficial (Deogun, 1937).

Bamboo being a very hardy plant comes up with on a wide variety of soils, derived from different parent rocks, within its climatic habitat. However, each species of bamboo has its own optimum site and soil conditions and rarely occur in mixture (or) in close association. Generally bamboos make luxuriant growth on hilly slopes and on well drained, sandy loam to loamy soils, with adequate supply of nutrients and moisture. *Bambusa bambos* and *Oclandra* which make good growth on clay soils and under moist situations such as the river and nala banks. The low level depressions, steep slopes are not conducive for the growth of bamboos.

Dendrocalamus strictus, one of the most widely distributed species of bamboo in our country, is well adapted to a wide range of climatic conditions. It thrives well under climatic conditions typifying xerophytic characteristics of evergreen forests. *Bambusa bambos* another widely occurring species next to *Dendrocalamus strictus* prefers heavy rainfall areas.

Bambusa bambos is somewhat exacting in its site and soil requirements. It prefers moist situations, seldom grows in dry areas and is most common along the streams, in depressions along lower slopes and other localities where moisture is available in large quantities. In dry tracts, it prefers to grow on alluvial (or) other deep, fine textured soils, which have high moisture retaining capacity. The growth of this bamboo is much inferior on dry lateritic soils than on moist deep alluvial soils.

The soils carrying *B. bambos* are finer in texture, more acidic, more retentive of moisture, richer in nitrogen, organic matter, iron and aluminum, exchangeable magnesium and available potassium than those dominated by *D. strictus* (Quresh *et al.*, 1969).

D. strictus prefers sandstone, granite, granitic geneisses which give rise to coarse textured soils having low water holding capacity. But it makes poor growth on micaceous and chlorite schists, quartzite and schistose gnesiss which produce fine textured soils with high water holding capacity.

Soil moisture regime has an important role in the distribution of various bamboo species so much so that the influence of geology becomes a secondary conditions to any of the soil characteristics that affect the soil moisture regime. Within an area having the same parent rock, the upper and middle slopes characterised by coarse texture and dry conditions are occupied by *D. strictus*, whereas the bottom lands characterized by fine texture and moist conditions are occupied by B. bambos. The natural regeneration and clump size of the bamboo are greatly affected by the moisture conditions of the soils.

Dendrocalamus strictus is a versatile species making good growth on a variety of soils derived from such widely varying parent material as granite, basals and rchirts. One of the essential conditions for its successful growth is the sandy nature of soil and good drainage. It prefers a dry soil and is a characteristic constituent of open dry types of deciduous forests. The various climatic, edaphic and biotic factors which accentuate dry conditions appears to be conducive to the dominance of this species. In moist localities the culms of *D. strictus* are usually hollow while in

dry tracts they are solid. This species gives way to *B. bambos* in moist localities (Yadav, 1968).

Bamboos are conspicuously absent on extremely acid, saline and alkali soils. They prefer acidic to near neutral pH. Bamboos avoid heavy clays in mixture with lime and water logging. Bamboos grown on poor dry and hard soils have been found to be of inferior quality.

Bamboos seldom occurs in pure forms but are generally found as an understorey to tree species in tropical evergreen, tropical moist deciduous, tropical dry deciduous, montane sub-tropical, montane wet temperate and Himalya wet temperature forests. Generally, the genera *Bambusa* and *Dendrocalamus* are found under tropical conditions, where as *Arundinaria occurs* in temperate region and is, by far, most common on high elevations in Western and Eastern Himalayas. *Dendrocalamus strictus* is prominant in dry deciduous forests, while *Bambusa bambos* flourishes best in moist deciduous forests. The most important bamboo of the semi-evergreen forests of the Andaman is *Oxytenanthera nigrociliata.* In the Eastern region, consisting of Bengal, Assam and N. E. Himalayas, the commercially important bamboos are *Bambusa tulda, Dendrocalamus hamiltonii* and *Melocanna bambusoides.*

The distribution and site factors of some commercially important bamboos occurring in India are presented in Table - 3.

LIST OF PLATES

Plate 1. Origin-of flat rhizome, from which culm bud appear. (See page No. 19)

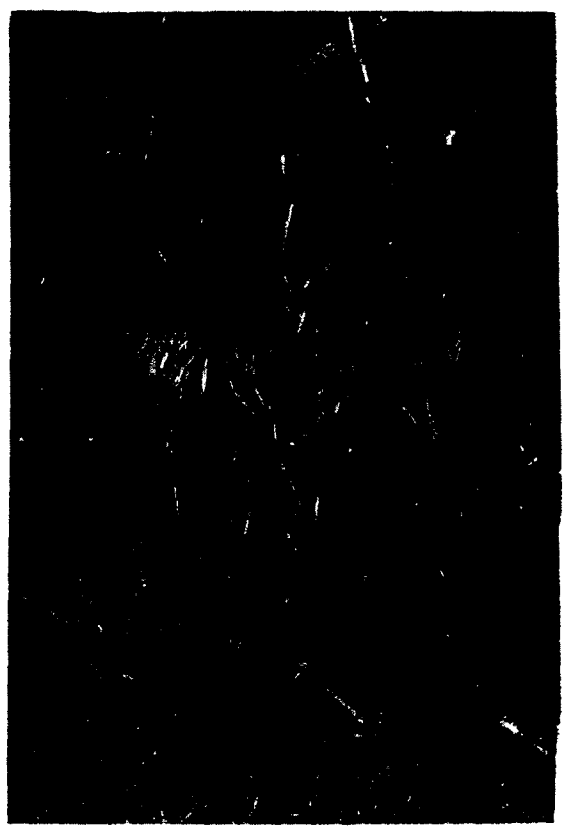

Plate 2. Internodes wrapped up in a single sheath. (See page No. 20)

Plate 3-A. Growth of culm
2nd day - 12 cm. (See page No. 21)

Plate 3-B. Growth of culm
4th day - 20 cm. (See page No. 21)

Plate 3-C. Growth of culm
6th day - 53 cm. (See page No. 21)

Plate 3-D. Growth of culm
3th day - 76 cm. (See page No. 21)

Plate 4. Falling off the sheaths that covers the bud meristem. (See page No. 21)

Plate 5. Clumps in a bamboo plantation. (See page No. 21)

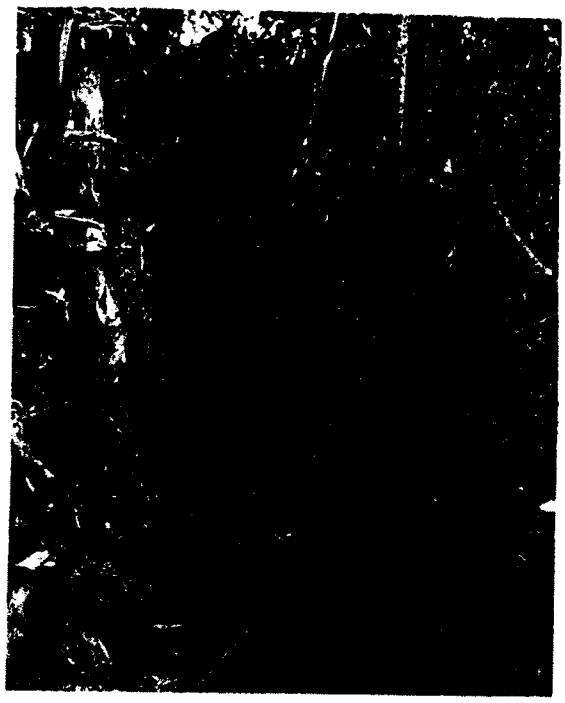

Plate 6. Congested culm in a clump.
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Plate 7. Seedlings like a grass.
(See page No. 32)

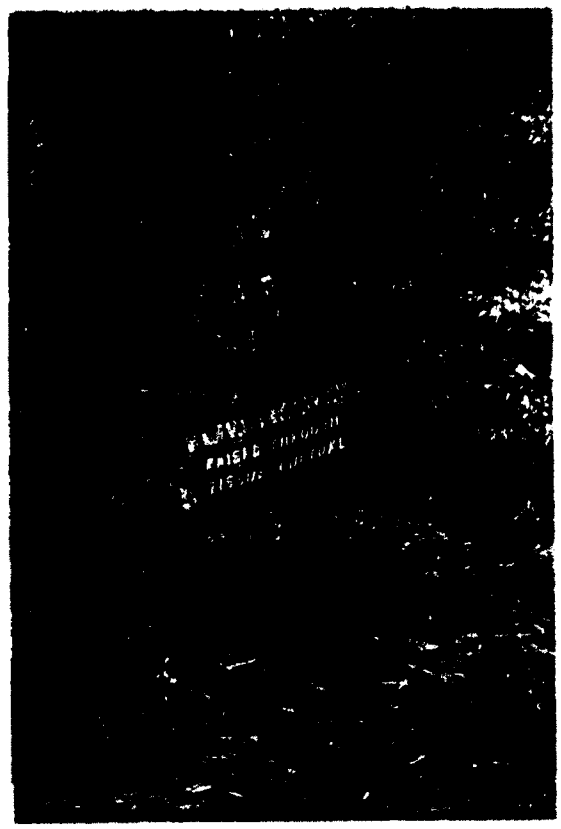

Plate 8. Transplanted seedlings. (See page No. 33)

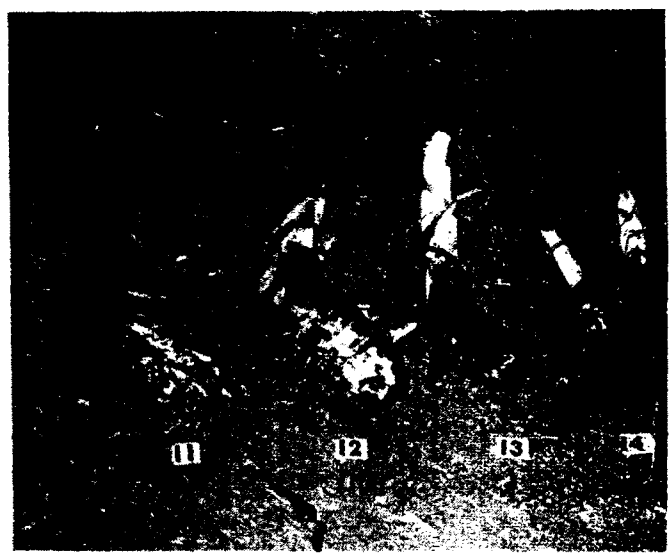

Plate 9. Rhizome with roots for transplantation. (See page No. 34)

Plate 10. Hardening of tissue cultured bamboo, ready for transplantation. (See page No. 43)

Plate 11. Clump formation. (See page No. 43)

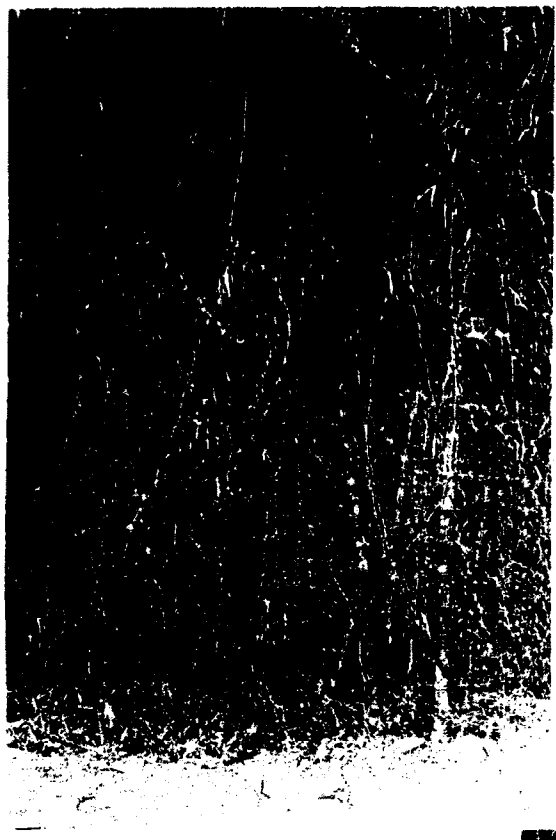

Plate 12. Unpruned clump.
(See page No. 48)

Plate 13. Pruned clump.
(See page No. 48)

Plate 14. Thorn emergence and leaf bud appearance.
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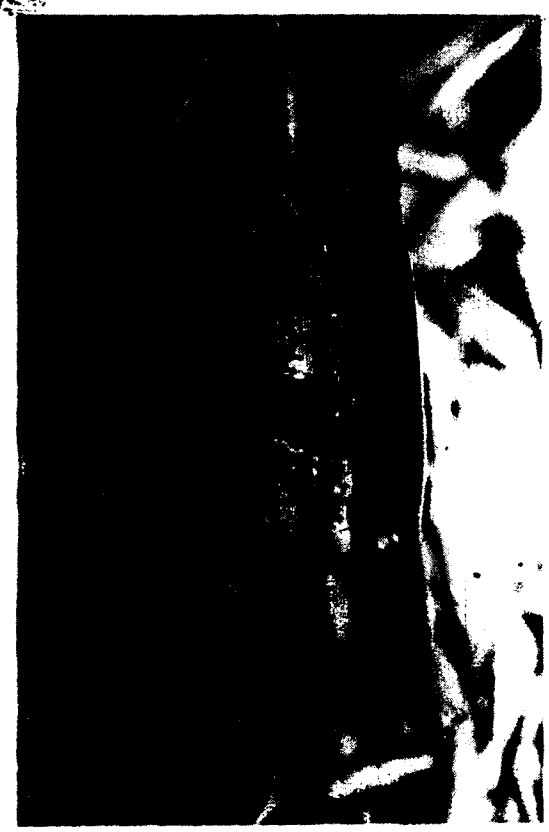

Plate 15. Young bud looking like a foolscap.
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Plate 16. A bamboo plantation at kallipatty.
(Note culm height 25 m).
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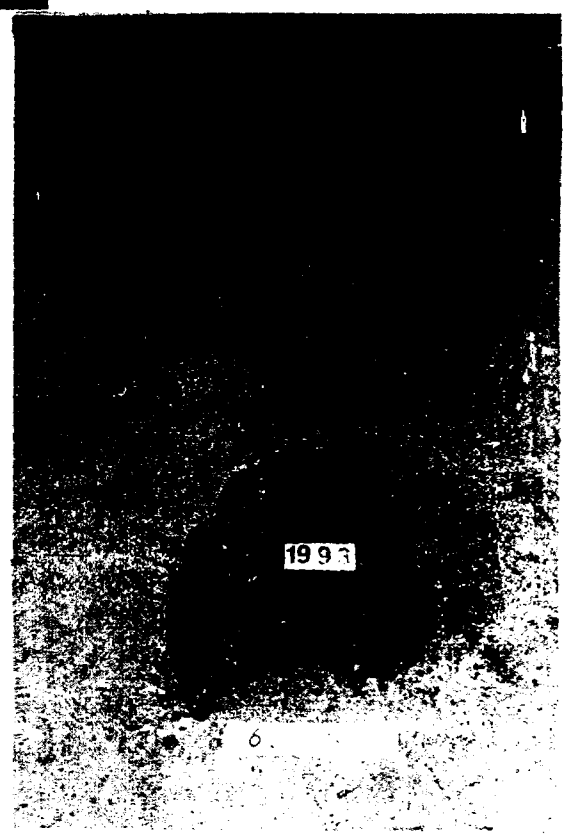

Plate 17. 6 Year culm with rhizome.
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Plate 18. Roadside strips (Dindugal - Madurai road)
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Plate 19. Road side plantation at vadipatty village. near Madurai, Tamilnadu. (See page No. 77)

Plate 20. Canal plantation. (See page No. 78)

Plate 21. Rehabilitation of degraded forest. (See page No. 84)

Plate 22-A. Bamboo plantation in private marginal lands.
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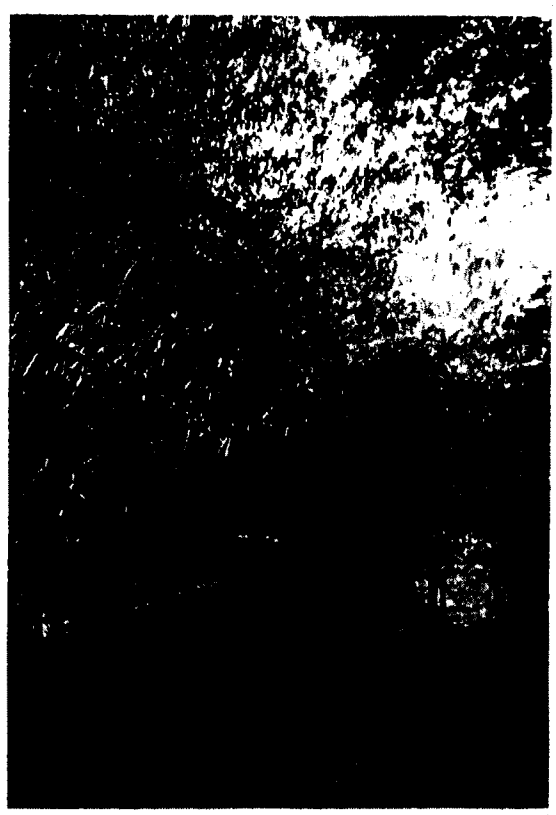


Plate 22-B. Bamboo plantation in private marginal lands.
(See page No. 87)

Plate 23. Clumps in the marginal lands.
(Rs. 1000/- could be got in three years from just one clump).
(See page No. 90)

Plate 24-A. Weaving of bamboo products. (See page No. 113)

Plate 24-B. Baskets and shutters.
(See page No. 113)

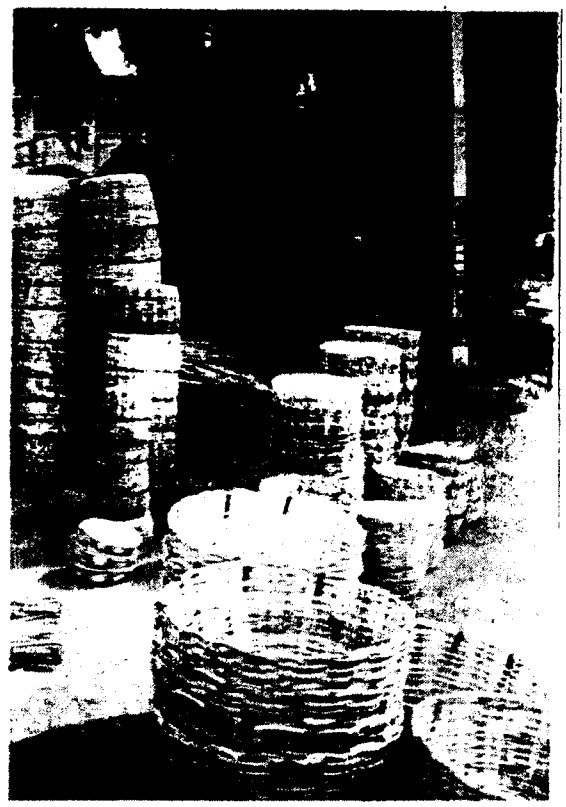


Plate 24-C. Various sizes of baskets.
(See page No. 113)

Plate 24-D. Padels, roofing. (See page No. 113)

CHAPTER - 5

GROWTH CHARACTERISTICS

5.1. Development of Bud

The bamboo forms a unique group of giant arborescent grass. Bamboo grows in two distinctly different forms due to the types of its subterranean rhizome., i.e. either single stemmed (or) monopodial (leptomorph) (or) densely clumped (or) Sympodial (pachymorph) (Figure - 3). A complete bamboo plant consists of three morphologic structures - the leafy aerial part (the culm) and the two underground parts (the rhizome and roots). For successful growth, all these structures must develop. Failure in development of any of these phases leads to complete failure. The stems are called culms and their joints nodes. A scaly rhizome (or) underground stem is produced from the base of the seedling-plant which after growing vertically downwards for a short distance, curves up again and appears as a small culm (bud) (Plate - 1).

The buds in rhizome are initially flat in shape, usually less than 2.5 cm in diameter and are covered profusely with scales. These scales are at first not very apparent, but develop rapidly as the buds develop. These scales are the underdeveloped sheaths of the future culm. On carefully dissecting away the scales one by one, it can be seen that a bud contains a complete bamboo in embryo. Each bud has as many as 35 (or) more telescopic internodes with an equal (or) large complement of scales in appearance, like the growth rings on the stump of a tree, in the form of a terraced mound. The bud which do eventually develop are usually one year old, often two year old but

seldom older than this. They start growth just before the commencement of monsoon, so that they appear above ground with (or) during the monsoon.

During the development of a rhizome bud (Figure - 4) into a culm, the first thing formed is a short new rhizome. Before the culm appears above the ground, the new growth develops into a complete rhizome for the support of the culm. At this stage, it is equipped with several fully grown buds, which in turn lie dormant until the following years (Figure - 5). The function of the rhizome is to give support to the growing aerial shoots (culms) and to act as a feeding channel. The feeding organs of a rhizome are the slender rootlets which are capable of going from a few centimetres to a metre, (or) so, deep underground.

The sheaths are of vital importance to culms during growth. Each internode is carefully wrapped up in a single sheath, (Plate - 2) but the basal internode always has more than one sheath. In a bud, the sheaths are arranged alternately clockwise and anticlockwise. The sheath is a nurse to the tender internodes against injury and desiccation. Its outer surface is armed with a cluster of stiff hairs, which are detached on the slightest touch and cause irritation to any naked part of the human body.

A bud is a complete miniature bamboo with a rhizome and culms. Similarly, a culm above ground is a complete aerial shoot irrespective of its size. There is no terminal growth. The height growth of the culm is caused by the successive elongation of the internodes. The lowest internode at the ground grows first and the top most one, the last of all. Several internodes from the bottom upwards grow simultaneously. The internodes, during development are concealed within the sheaths. It is usually after the

internodes have completed more than 3/4th of their height that they become visible above the edge of their sheaths. The upper part of the internode completes its growth fast and then the growth activity is confined to the lower region and continues till maximum growth is reached. Completion of elongation of internode takes place within a few days, say about 15 days at Kallipatty (Shanmughavel, 1995). More than one internodes grows at a time, but the number of such internodes growing simultaneously is limited to about 5 to 8. In the early stages, the height growth of a culm is slow, about 10 to 15 cm per day (Plate - 3). After the culm has reached about 3 meters in height they start shooting up very fast, often 30 cm in 24 hours, in the case of *Bambusa bambos* at Kallipatty, Tamil Nadu. In bamboos, even a large culm of 35 metres height attains its full height in 2 - 4 months and then culm tissues harden the internodes become hollow and branches with leaves are formed in the upper part, after the nodal sheaths wither (Plate - 4). Each internodes has the growing zone and it elongates even if the apex of the sprout is cut off (or) the culm sheath is peeled off slightly. In some species like the Giant Bamboo, the sheath covered shoots emerge from the soil at the rate of four centimeters per hour. So rapid is the growth on moist, warm mornings that we can actually hear the shoots grow; they make loud squeaking and whining noises as they pierce through the enveloping sheaths.

5.2. Clump and Culms

Most bamboo species of commercial importance form clumps (Plate - 5). The new seedling produces rhizomes which develop new rhizomes that inturn produces culms. New rhizomes are produced from the previous year rhizomes. The number of new rhizomes may vary from one

to many (Figure - 6). Some seedlings fail to produce clumps. This may be due to selfing or depression. In India new culms generally appear during the rainy season. An unusual rain during winter months may induce the emergence of new culms. Though the culms do not grow in diameter after sprouting, they continue change in density and strength properties.

Two kinds of buds are observed on the rhizomes, the scally pointed buds and the flat buds. The former develop into rhizomes and the latter into culms. The scaly buds are formed during the summer months while the culm buds develop during the winter months. The culm buds emerge out of the soil with the early rains and grow rapidly. The culms are very tender during the growing period. They are sometimes art and made into vegetable (or) pickles. The age of an individual culm is not related to clump age. Culms are tender during first year. They grow tough during the second year and are mature during the third year. At the age of three years they acquire full density and strength. After this age they start changing colour. Depending on the climatic conditions and the species culms dry up between 4 and 12 years. They die up earlier in dry localities and have a longer age in moist localities.

Most bamboos have hollow culms; very few have solid culms, e.g., *Dendrocalamus strictus, Dinochloa, Bambusa pygmea* etc. In rare cases the culms is filled with pith, e.g. *Actinocladum verticillatum*. In the case of bamboo having hollow culms, the walls may be thin (or) thick. The culms may be erect (or) arching outwards in most of the bamboos and semiscandent (or) scandent in few. e.g. *Dinochloa* spp. The Zigzag culms (the straight internodes at an angle from the nodes) is a unique feature of *Dinochloa* spp. There is even a bamboo (*Bambusa*

angulata) with a square cross-section. In giant bamboo, *Dendrocalamus giganteus*, the culms may reach a height of 35 m and a diameter of 30 cm, whereas in the smallest bamboo, *Arundinaria pygmea* the culms do not exceed half a meter height and 1 cm diameter.

5.3. Rhizomes

Rhizomes generally grow at an upward inclined angle. The angle of incline depends on the species and the condition of soil. During this period of growth any exposure to sunlight stops the rhizome development. Consequently, the bamboo culms that are covered with earth (or) humus produce more culms while in areas where soil erosion takes place, the production of new culms gets reduced. The rhizome development is not peripheral as generally believed. Rhizomes may develop in any direction and the culms may appear anywhere in the clump provided overhead light is available for the emergence of the culm. It is only in congested clumps (Plate - 6) that the new culms appear to grow at the periphery. The new culms can even be seen in the middle of the clump.

5.4. Flowering

Bamboos differ significantly from other vegetation because of the mechanism of flowering. Most of the woody bamboos flower and seed after an exclusive vegetative growth for a species specific supra annual interval, ranging between 3 and 120 years (Janzen, 1976). There are three types of flowering (i) Those which flower gregariously and periodically (ii) those which flower irregularly (or) sporadic (iii) those which flower annually. In gregarious flowering all members of a cohort (Plants from seeds of common origin) enter the reproductive phase approximately at the same

time and after flowering and seeding the parents die enmasse. This death of the bamboo parents used to be given more importance, probably because of their long intermast periods and arborescent habits. It has to be considered as a character bamboos share as members of the grass family (John *et al.*; 1993). The characteristics of gregarious flowering are,

(i). flowering occurs almost over the entire area

(ii) it involves almost all (or) some proportion of the culms

(iii) flowering takes place in all the clumps

(iv) flowering is followed by the death of the clump

(v) it follows a cycle which occurs after a long interval

(vi) it progresses in a definite direction like an epidemic wave beginning at one definite edge of an area and

(vii) it takes a few years, commonly between two to four years to complete flowering in the area.

(eg.) *Bambusa polymorpha, B. bambos* and *Melocanna beccifera* etc.,

In sporadic flowering members of a cohort enter the reproductive phase at different times (or) at irregular intervals and after flowering (and seeding) the parents do not die but revert to vegetative growth. Important characteristics of sporadic flowering are,

(i) scattered nature of flowering with only a few clumps involved in flowering

(ii) only a few culms flower in a clump

(iii) the culms may (or) may not die after flowering

(iv) the clump does not die and

(v) usually it takes place irregularly almost every alternate year

(e.g.) *Dendrocalamus strictus, D. hamiltonii Gigantochloa* app, *Oxytenanthera* spp, etc.,

Some bamboos, flower annually (or) nearly so (e.g.) many hill species like *Indocalamus wightianus, Bambusa atra* and *Oclandra scriptoria*

Due to this peculiar flowering behaviour in bamboos, flowers and seeds are available only at very long intervals. This has resulted in a poor understanding of their inter-relationships, besides making the perennial raising of plantations using seeds and hybridizations difficult. Selection is the only method available at present for bamboo improvement (John *et al.*, 1994). It is possible now to induce flowering is bamboos by tissue culture methods (Nadgauda *et al.*, 1990). Induction of flowering *in Vitro* can be used for perennial seed production and hybridizations.

The physiology of bamboo flowering is still not fully understood. It is one of the mysteries about, all culms and clumps of a species start to flower at the same time, irrespective of their age and the distribution over large areas. Thus from an economic point of view, bamboo flowering and fruiting is something of calamity since the culms and root stocks degrade afterwards rather quickly and are no longer available for the rural and urban population and the pulp industry. Consequently intensive

research has focussed on the reasons for the sudden and quite unpredictable simultaneous flowering of the solitary bamboo species. There are several theories and indications, but so far no definitive cause has been established. The involvement of plant physiologists and biochemists required for explaining, predicting (or) even preventing (or) inducing the flowering of bamboo.

Flowering and the subsequent superabundant fruiting consumes all energy reserves stored in the parenchyma cells of the culm and the rhizome. This may contribute to their death soon after. Estimates of flowering interval for some of the species are as under.

Ochlandra travancoria	7 years
Drepanostachyum falcatum	28 - 30 years
Thamnocalamus spathiflorus	16 - 17 years
Himalayacalamus falconeri	30 years
Arundinaria racemosa	30 years
Dendrocalamus strictus	30 -70 years
Dendrocalamus hamiltonii	30 - 40 years
Bambusa tulda	30- 60 years
Bambusa polymorpha	55 - 60 years
Bambusa bambos	30 - 45 years
Melocanna baccifera	45 years
Schizostachyum sps.	30 - 40 years

5.5. In vitro flowering of Bamboo

The secret of bamboo's shy flowering most species flower once in 30 years (or) even longer - may soon be bared, thanks to a much acclaimed piece of research done by Nadgauda *et al.*, (1990) from the National Chemical Laboratory (NCL), Pune. They have shown that bamboo species which, in nature, would have flowered only after a specific period can be induced to flower in a few weeks in the laboratory. The work, which also opens the door to genetic improvement in bamboo. Considering the importance of bamboo in the culture of the Eastern countries, the finding may well be the harbinger of a bamboo revolution. With hybridisation now made feasible, bamboos flowering at different intervals can be crossed and varieties tailored to suit specific needs.

The flowering in bamboo is so unpredictable that no breeding work can be carried out. Not two species flower together. The Indian species flower once in 100 to 120 years. With the newly developed method of inducing precocious flowering, universal studies can be carried out. We can now do studies to elucidate the mechanism of flowering in bamboo in terms of molecular and biochemical processes.

Another curious aspects is that all plants of a species derived from the same seed flower simultaneously, wherever they may grow. Bamboo taken from India and China to European gardens have been known to flower in perfect synchrony with the parent stock. It is as if each cell of a particular stock contains a time-keeper.

More than one myth is associated with the flowering of bamboos. According to one, bamboo flowering presages famine. But the actual sequence of events may

un thus : the flowering, followed by seed setting, attracts rats in large numbers from neighbouring areas. The rats gorge themselves on the seed and multiply prodigiously. The next year they are deprived of this food supply and the rats attack standing crops in the surrounding areas, resulting in severe crop loss which leads to famine conditions.

No doubt a few species of bamboo do flower annually, but according to Nadgauda *et al.*, (1990) these are not the tree - like bamboos; nor do they flower gregariously. The usual flowering intervals may be 3, 20, 60 (or) even 120 years, the most usual being 30 years. Flowering takes place only once in the lifetime of the plant. The long intervals between flowering have posed problems for the plant breeder wishing to cross two (or) more species. The National Chemical Laboratory, Pune paves the way for simultaneous flowering and hybridisation of different species, which flower at intervals of say, 30 years and 60 years respectively.

The NCL team used the tissue culture technique in which the growing regions, such as the shoot tips, are used to obtain a large number of plantlets in the case of species which are rare (or) flower at long intervals. Tissue culture is similar to using cutting except that the cuttings are very minute and yield a large number of daughter plants. Seeds of the species Dendrocalamus brandisii and Bambusa bambos were germinated. After eight days, segments containing the growing tips, along with the sheaths, were incubated at 280 C on a rotary shaker. Individual shoots were cut and grown on a culture medium supplemented either with coconut milk (or) other growth regulators, singly (or) in combination.

Sixty per cent of the shoots give rise to inflorescences (or) flowering shoots, which could be multiplied indefinitely. The flowers, which were 12 mm in diameter, also set seed in the laboratory. Normally the two species would have grown without flowering for about 30 years, but in the laboratory, they flowered in a matter of weeks after germination. The NCL scientists have repeated the work with *Dendrocalamus strictus* (Male bamboo) which is important in the paper and pulp industry. They are planning to under take genetic improvement in bamboo.

It is impossible to overestimate the importance of breeding work in bamboo. The research carried out in this field lays the foundation for the exploitation of the tremendous genetic variation available in bamboo. The greatest of the grasses that so escaped, being domesticated and cultivated by man, may at least be tamed.

CHAPTER - 6

ESTABLISHMENT AND MANAGEMENT

Bamboo plantations can be raised by several methods

6.1. Direct sowing of seeds

6.2. By culm with roots and rhizome

6.3. By the stock with roots and rhizome

6.4. By rhizome with roots

6.5. By offset planting

6.6. By the cutting of culm

6.7. By branch cutting

6.8. By tissue culture and Macroproliferation

6.1. DIRECT SOWING OF SEEDS

6.1.1. Seed characters

Possibilities of raising bamboo plantations from seeds are not always practical because of the unusually long seeding cycles. Except in the case of Melocanna baccifera, seeds of most of the commercially important species of bamboo resemble grains of paddy (or) wheat and are light in weight. Seeds for direct and nursery sowing should be obtained direct from the forest. The seed may be collected either on the ground previously cleared (or) on a

cloth spread around the culm, by shaking the culms. The best time for collecting the bamboo seeds is between the months of February and July consequent to the flowering. The number of seeds per kilogram varied from 75,000 to 1,05,000. The bamboo seeds remain viable for short periods, with the initial viability is good, the seeds rapidly lose germination vigour. The longevity of seeds varies from species to species but they are generally viable upto 1 -2 months, although the period can be increased under controlled storage conditions. Seeds of *Bambusa tulda* stored in a desiccator over silica gel maintained their viability even after 18 months (Banik, 1987). By storage of seeds under suitable temperature and moisture, the longevity of *Dendrocalamus strictus* seeds could be extended upto 34 months (Gupta and Sood, 1978). The viability of seeds varied from 30 - 35 days for *Bambusa tulda*, 55 days for *Dendrocalamus longispathus*, 65 days for *Bambusa bambos.*

Seed of *Thyrostachys siamensis* can be stored for about 27 months under controlled conditions (Anantachote, 1985). Seed viability can be extended by reducing the initial moisture content before storing, which helps in maintaining viability upto 9 months. Seed samples stored at room temperature losts their viability within 21 months, in comparison with seeds stored for 27 months under low temperature such as in the cold room (2 - 40 C) and deep freezer (-50 C), can maintain a high percentage of viability (89.2 - 92.5) and were able to germinate within 3 - 4 months (Ramagarangasi, 1988).

Seeds should be given pretreatment before sowing, i.e. normally soak in water for 48 hours. Bamboo germinates generally within 5 -10 days of sowing and the seedlings attain 1-leaf stage in 7 days. Percentage of

germination is higher when seeds are sown directly in polythene bags rather than in nursery beds.

6.1.2. Direct sowing

For direct sowing, the soil should be dug upto a depth of about 10 -15 cm, (or) deeper in case of poor soils, either in lines 3 m apart, (or) in patches 3 m x 3 m (or) 4.5 x 4.5 m apart and cleared of all weeds. Seeds, after having been soaked for 48 hours before sowing are dibbled in beds at the plantation site and slightly mulched. The resultant plant kept clean weeded for the first 2 (or) 3 seasons. 1.25 kilogram of seed per hectare will suffice for widely spaced patch sowing and about 11.5 kg for line sowing. Though direct sowings are an easy method, they are generally neither practicable nor desirable owing to shortage of seed, the necessity of continues weedings till plants are well established, and the liability of destruction by seed eating birds and rodents.

6.1.3. Transplanting

As direct sowings in lines are often liable to fail due to relatively (i) uneven germination (ii) slow growth of resultant plants and (iii) exposure to animal damage etc. the more usual procedure is to raise plants in a nursery bed for transplanting entire plants. For this purpose the nursery site should be located well within the planting region and near an adequate supply of water.

At first the seedlings look like grass (Plate - 7), whippy shoots appearing after a few months. Great care is required in planting out bamboo seedlings, which are liable to wither if the roots are exposed to the sun. Planting should be done as quickly as possible, before commencement of monsoon season. Transplanted

seedlings (Plate - 8) were irrigated two hours regularly twice a day both in the morning and evening. Weeds should be removed from the plantation area as and when required. After one year, the plantation should be adequately irrigated at 15 days interval. Care must be taken to avoid waterlogging and protected against rodents, grazing and browing animals. Percentage of germination will be higher when seeds are sown directly in polythene bags rather than in nursery beds.

6.2. BY CULM WITH ROOTS AND RHIZOME

The culms of this method are used, the new young ones sprouted in the same year (or) the previous year. Although the large-size culms are preferable and also the small-size ones can be used. Leaving the branches with several nodes, the culm with branches of upper part is removed (Figure - 7). The rhizome of the culm should be young, vigorous and bearing good buds. Old rhizomes should not be used, for they are lacking the buds that develop into culms. The length of rhizome is 40 - 60 cm in length with about ten nodes and buds. Fibrous roots on both culm and rhizome must be leave. The rhizome should be cut carefully with a saw, cutting with a hatchet will cause damages to the buds.

6.3. BY STOCK WITH ROOTS AND RHIZOME

In this case the culm is branchless and its length is about 30 cm. The procedure is the same as shown in above method (Figure - 8).

6.4. BY RHIZOME WITH ROOTS

Rhizome without culms are cut 50 - 60 cm long with about 10 - 15 nodes and their roots. The 2 - 3 year

old rhizomes with roots are most satisfactory, but over 5 year old rhizomes are entirely unsuitable. This method is recommended for transplanting to distant places. In this case, they are wrapped with sphagnum moss and covered with vinyl sheets after the soil is washed away. Usually, they are first laid in the nursery bed 20 cm deep and covered with soil (Figure - 9). They are transplanted next spring, as new culms begin to grow. This method is applicable to monopodial type (Plate - 9).

6.5. BY OFFSET PLANTING

This is the good method of vegetative propagation of clump - forming bamboo species in which success has been achieved. One year old culms which are ready to sprout within the year are cut off with short rhizomes. The culm should be about 30 to 50 cm in length. The success of this method depends in part on the vitality of the rhizome stock used and the time of the year when it is planted. If the rhizomes are taken from young healthy stock and planted immediately at the break of rain success can be expected. But if the rhizomes are taken from old stock and planted much before the rains, complete failure may result. The weather of the year must also be an important factor (Figure - 10).

6.6. BY CULM CUTTING

This method, however, has a limited use because of the limited availability of the planting material. Rooted culm cutting can be successful with most bamboo species. The age of the culm and the period when these cuttings are put out for rooting are important considerations. The two year old culm and spring season have been found to give best results.

However, a method of vegetative propagation using culm cuttings has been standardized at the Kerala Forest Research Institute (KFRI).This involves treatment of culm cuttings with growth regulating substances for including root formation. The method was tested for (*Bambusa bombos, B. balcooa, B. polymorpha, B. ventricosa, B. vulgaris, Dendrocalamus brandisii, D, hamiltonii, Ochlandra scriptoria and O. travancorica*) 12 species of economically important bamboos and was found successful. Large scale multiplication of superior varieties is possible by this method. When outplanted, plants raised from cutting develop to clumps much faster than seedlings. This portion describes the practical steps involved in propagation of bamboo through culm cuttings.

6.6.1. Collection of material and preparation of cuttings

Extract 2 to 3 years old culms from healthy culms by cutting just above the first node during March - April. The leaves and side branches should be trimmed. Care should be taken not to injure the auxiliary buds while removing leaves and branches. The culms should be transferred to the nursery site as quick as possible. Maximum care should be taken to prevent drying. This can be done either by wrapping in moist gunny bags (or) embedding in boxes containing moist sawdust. Two - noded cuttings (a cutting with two nodes leaving about 5 - 7 cm on either side of the nodes) should be prepared using a sharp knife (or) saw. For bamboos with thin walls use of a saw is advised to avoid splitting of the cut ends. Make an opening (about 2 cm in length and 1 cm in width) (or) drill two holes (about 7 mm diameter) in the centre of the internode.

6.6.2. Treatment for root induction in cuttings

10 gram of NAA (1-Napththlene acetic acid) BDH, Loba Chem (or) E. Merck), should be dissolved in 250 ml of ethyl alcohol (90%) in a container by stirring the solution gently and add water to make up 100 litres. The solution is mixed thoroughly by stirring. The final concentration of NAA will be 100 mg/1 of water (or) equivalent to 100 ppm. This solution is sufficient to treat 1000 cuttings. About 100 ml of the solution should be poured to the culm cavity. To avoid spillage, use a wash bottle to pour the solution through the drilled holes. The holes should be closed by wrapping and trying with a polythene strip (60 cm x 6 cm). Ensure that the polythene wrapping should be tight so that the solution does not leak out. The cuttings should be kept horizontally with the opening facing upwards. For bamboos with narrow culm cavity like *Dendrocalamus strictus* the treatment is given by dipping the basal portion of the culm cutting in solution of NAA for 24 hours. After extraction, the culm cuttings should be treated with NAA as quickly as possible (preferably the same day). If the planting site is far away and there will not be unavoidable delay for planting, the treated cuttings can be preserved up to three days by keeping in moist sawdust.

6.6.3. Preparation of nursery and planting

Raised nursery beds of 10 m x 1m is prepared and filled with a mixture of soil and sand (3 : 1). One weak prior to planting, drench the nursery bed separately with the insecticide, Aldrin and the fungicide, Bavistin to prevent termite and fungal attack. For each bed, use to 40 litres of 0.015% (9.1). Aldrin prepared by adding 0.5 ml of Aldrex 30 EC per litre of water and 30 litre of 0.05% (9.1).

Bavistin prepared by adding 1 g of bavistin 50 WP per litre of water. The treated cuttings were placed horizontally (the opening facing upwards) across the nursery bed. About 50 - 60 cuttings may be conveniently planted on a raised nursery bed of 10 m x 1m. The cuttings were covered with a thin layer (2 - 3 cm) of soil.

6.6.4. Nursery management

Nursery beds must be provided with a thatch to protect the cuttings from direct sunlight, which may be removed on the onset of monsoon. The beds should be watered regularly in the morning and evening with 30 to 40 litres of water pre bed at each watering. Care should be taken to avoid water logging. The sprouts after one month were treated with 0.01 % of Bavistin to avoid fungal attack. If necessary, farmyard manure may be applied increase the vigour of the sprouts.

6.6.5. Transplanting

Rooted cuttings can be uprooted and transplanted to the field during June - July (after about 4 months). If cuttings are sprouted and rooted at both the nodes, cut should be done carefully at the middle of the cutting to get two plants.

6.6.6. Precautions

The collection of culms from clumps which are likely to flower in the near future is to be avoided, because new clumps developed from such cuttings will also flower and perish along with the mother clump. The year in which the clumps are likely to flower can be found out by checking the previous flowering record the area and the flowering cycle of the species.

6.7. BY BRANCH CUTTINGS

In this method, branch cuttings should be taken from the bottom, middle and top portions of the healthy culms in the clump, with a sharp knife. The branches should be cut at its basal portion, the leaves and side branches were removed and cuttings with two internodes were prepared. The cuttings should be immediately transferred to the nursery. A natural rooting medium (mixture) should be prepared by mixing rice husk, dried powdered cow dung, charcoal and sandy soil in equal proportions. The mixture will be filled in black polythene bags of 45 cm height. The cuttings were inserted into the mixture vertically. The planted cuttings should be placed in a thatch to protect from direct light. They should be regularly watered in the morning and evening. The cuttings sprouted within 20 - 30 days after planting, and root development, can also be observed within this period. Rooting efficiency will be better in the samples taken from the bottom region. The branch base later changed to develop from that region. The rooted cuttings should be transferred to the soil in August. July and August are suitable season for the vegetative multiplication of bamboo using branch cuttings. The method has the following advantages.

i) It is simple and can be adopted by the farmers

ii) There is no need of costly chemicals like hormones

iii) A large number of propagules can be obtained without cutting the culm

6.8. BY TISSUE CULTURE AND MACROPROLIFERATION

Large scale production will be hampered by the long vegetative cycle and death of the flowered clumps, coupled with low speed viability. Although planting stock can be produced by vegetative propagation, the synchronous flowering of the vegetatively propagated clumps and parent clumps leads of the death of the entire plantation. At this juncture tissue culture assumes great importance to replenish the acute shortage of planting stock as the cultures can be maintained in juvenile phase for long durations.

6.8.1. Tissue culture of Bamboo

The concept of tissue culture is borne out of the fact that, every cell in a plant is capable of regenerating into an entire plant, thus making it possible to regenerate innumerable number of plants from a single bud. A number of protocols are published for multiplication of bamboo. All the available protocols were tested and viable protocol for mass multiplication and transfer to field developed at plant Biotechnology Division of Forest Genetics and Tree Breeding, Coimbatore. Protocols for multiplication have been developed for *Dendrocalamus strictus, Bambusa bambos, Dendrocalamus asper* (edible bamboo), *Phyllostachys edulis. Dendrocalamus giganteus* and *Bambusa polymorpha.*

6.8.2. Collection of the bud materials

The single nodal buds from identified phenotypes (or) axillary buds from seedlings/young plants can be taken as the basic material for culture. The time of collection of bud materials from the mature culm is critical. They should

be collected at the time when the buds start swelling. In case seedling material will be used as explant, nodal portion from one month old seedlings can be prefered for multiplication.

6.8.3. Sterilisation of explants

The buds should be washed thoroughly with running water and sterilised with 0.1 % Sodium hypochlorite for 5 minutes, washed with sterile distilled water and with 0.1 % Mercuric chloride for 5 minutes; and all traces of the sterilant should be removed by rinsing with sterile distilled water. In the case of nodel explants from mature culms more rigorous sterilisation will be advocated.

The entire operation is carried out in the laminar flow chamber to maintain aseptic condition. The explants are initiated in Murashige and skoog medium supplemented with 0.5 mg / ltr Benzyl Amino Purine. The culture should be maintained at a photoperiod of 12 hrs dark and 12 hrs light with cool fluorescent lamps (100 m mol m-2 s-1).

6.8.4. Preparation of media

The buds should be initiated in a medium containing essential nutrients for growth. Basic bamboo culture medium ideally suited for multiplication is follows.

6.8.5.a. Bamboo culture Medium (Stationary liquid culture) developed at Plant Biotechnology division of Institute of Forest Genetics and Tree Breeding, Coimbatore.

Compounds	mg/1tr
Ammonium nitrate	1650.00
Potassium nitrate	1900.00
Calcium chloride	440.00
Magnesium sulfate	370.00
Potassium dihydrogen phosphate	170.00
Potassium iodide	0.83
Boric acid	6.20
Manganse sulfate	22.30
Zinc sulfate	8.60
Sodium molybdate	0.25
Copper sulfate	0.025
Cobalt chloride	0.025
Ferrous sulfate	27.84
Ethylene diamine tetra acetic acid	37.30
Myo-inositol	100.00
Nicotinic acid	0.50
Pyridoxine	0.50
Thiamine HC1	0.10
Glycine	2.00
Sucrose	30000.00
Benzyl Aminopurine	0.50

The above chemical should be weighed accurately and dissolved in 1 litre double distilled water. The pH of the media will be adjusted to 5.0. The media will then dispensed into jars covered with suitable enclosures and sterilised in the autoclave for 20 mts at 15 lbs pressure. The media may need modification depending on the physiological status of mother plants at the time of bud collection. For explants derived from seeds modification not necessary.

6.8.5.b. Sub culture

Within one month of culturing, the buds will be start producing multiple shoots. Regular subculturing should be done every 20 - 25 days in the same medium. Within 20 days, about 20 - 30 shoots will be produced. These are further subcultured with three shoots per flask.

6.8.6. Rooting and outplanting

Much of the shoots of prolonged culture will be rooted in the same medium. 90% of the plants root successfully in MS half strength medium supplemented with 0.1 mg/1tr Indole Butyric acid. Micro rhizomes are also induced under in vitro condition so that plantlets become hardy. This also ensure high survival rate when transplanted in polybags. The rooted plants with micro-rhizome will then transferred to a medium containing sand, soil, vermicullite in the ratio of 1:1:1 and should be kept in poly globule for hardening for a period of two weeks. If required, during this period 0.1% Bavistin sprayed to avoid fungal attack. Subsequently, the polyglobules should be opened and the plantlets kept in shade house for a period of one month and then should be transferred to the field. While the plantlets kept in shade house for a period on one month and then should be transferred to the field. While the

plantlets kept in the shade house, Hoagland's solution should be fed to the plants to enable them to rapidly gain height and dry matter. Within a month the hardened plants can be transferred to the field. (Plate - 10).

6.8.7. Transplanting

The seedlings should be planted at 6 m x 6 m spacing with a total of 250 seedlings per ha. The transplanted seedlings should be irrigated two hours regularly both in the morning and evening. Weeds should be removed from the plantation area as and when required. After one year, the plantation should be adequately irrigated at 15 days interval. Care should be taken to avoid waterlogging and protected against rodents grazing and browsing animals.

6.8.8. Production of culms

All transplanted seedlings began to produce rhizomes. From these rhizomes lateral culms were emerging which are the chief causatives for the total biomass yield. The number of culms developed from the rhizome totally constituted to a clump (Plate - 11). The productivity of bamboo is assessed by the number of new culms produced annually. At a given site the production of new culms is mostly dependent on the culms of the previous year, the degree of congestion and the clump age.

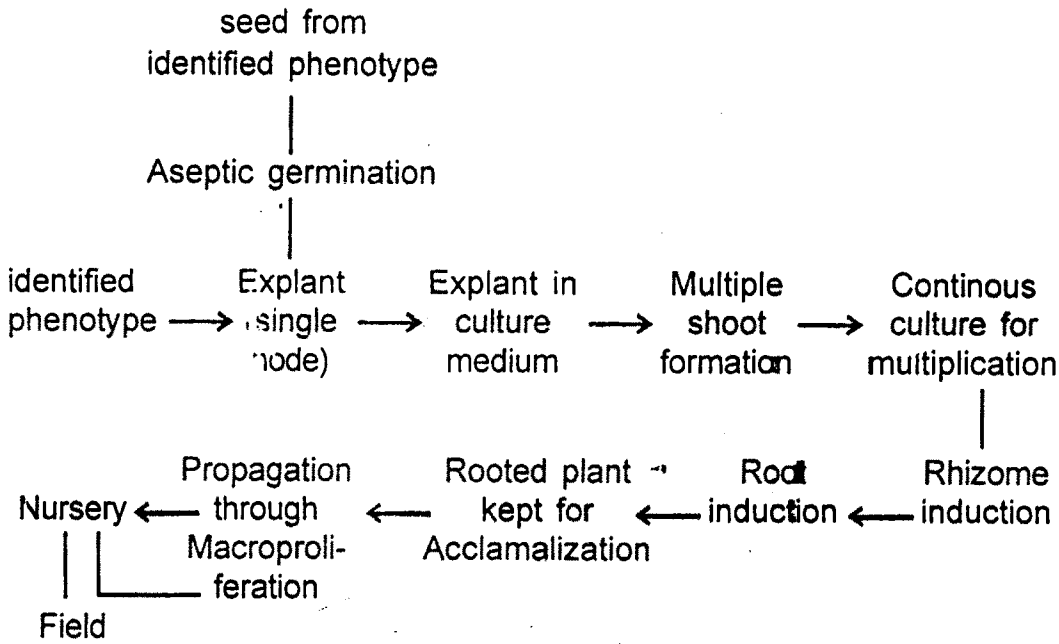
6.8.9. Macroproliferation

In order to increase the planting stock before transfer to the field, macroproliferation should be practiced. Four to five months old plants in the nursery developed with the above procedure has good rhizome system. These plantlets in the nursery develop five (or) six tillers at fours to

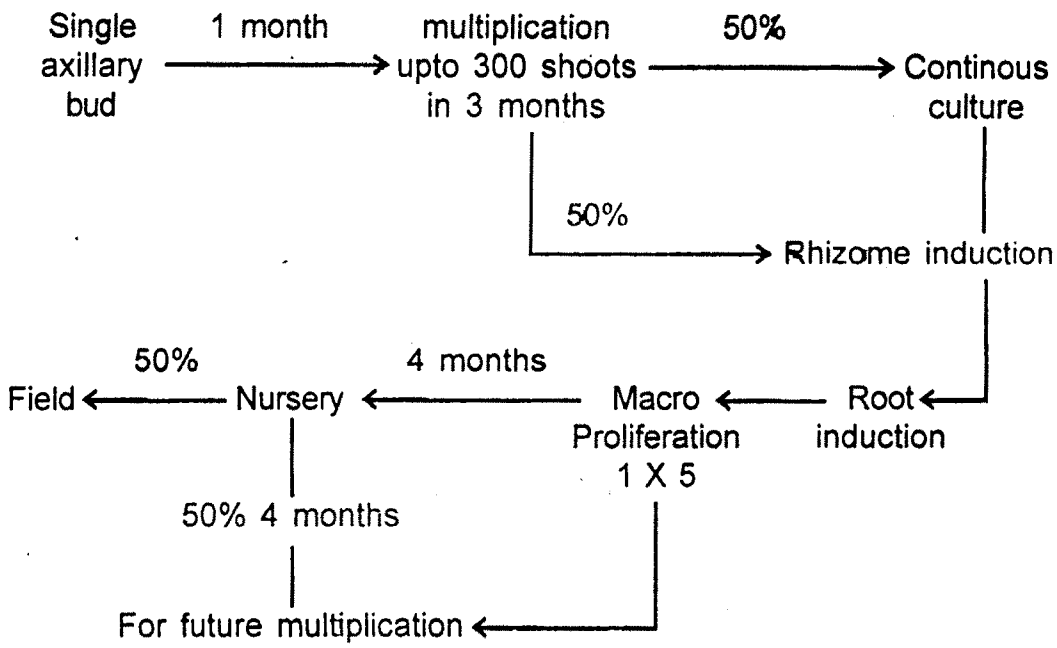
five months period. These tillers should be separated along with a small piece of rhizome and roots. These propagules will four months (or) they can be further multiplied through macroproliferation.

Thus by this technology a large number of identified planting stock can be made available. Using this technology one bud can be made to produce three hundred plants in three months which can further be multiplied on a larger scale. Essentially the approach will be same for all the species of bamboo, viz., *Dendrocalamus strictus, Bambusa bambos, Dendrocalamus asper* (edible bamboo), *Phyllostachys edulis, Dendrocalamus giganteus and Bambusa polymorpha.* Varying the cytokinin concentration and effectively subculturing with a period of 20 - 25 days would help in continous production of propagules with high multiplication frequency. The propagule production can be limited by manpower availability for subculturing frequency and space availability in the tissue culture laboratory and rapidity with which it can be transferred to the field. Several thousands of propagules can be produced by careful planning and anticipating the limitations. It is advisable to obtain the total planting sock requirement, atleast a year in advance and work - back the multiplication strategy.

PLAN FOR MASS MULTIPLICATION OF BAMBOOS



TIME FRAME FOR PROPAGULE PRODUCTION OF BAMBOO WITH APPROXIMATE MULTIPLICATION RATE



6.8.10. Season of Planting

The time of planting is a most decisive factor in the ultimate success of the plantation. Planting work must be undertaken immediately after the first showers of the monsoon. If it is rhizome planting, when the buds on rhizomes slightly show a sign of swelling, it is the best time for the selection of good shoots. Caution must be taken in transportation of such rhizomes for prevention of injury of the buds. The suitable irrigation is recommended when bamboos should be planted in mountain area. The new shoot that have sprouted in the same year may be planted very carefully with rhizomes during the rainy season in and after June. In the tropical regions, the rainy season from spring to summer will be the optimum season for planting.

6.8.11. Number under Planting

When the soil is fertile (or) the species will be of large - size culms, plantation should be done less densely than the case of poor soil (or) of the species developing culms of small size. Generally, the number to be planted should be 300 - 500 per ha (space 4 - 6 m). So, before planting the soil analysis should be carried out, to study the nutrient status in the soil.

6.8.12. Method of planting

Instruction for planting are as follows;

i) The junctions of culms and rhizomes should not be injured

ii) The bamboos should be planted, after being dug up as soon as possible. For the transportation to a distant place, rhizomes should be cut with roots

but without the culms and then wrapped with sphagnum moss after the soil has been rinsed away

iii) After planting, they should be irrigated and fertilized. The direct contact of fertilizers with the bamboo roots should be avoided. The fertilizer should be applied in the following proportion per ha. 200 kg of 15:15:15 N.P.K. fertilizer will be sufficient for increasing the production of culms.

iv) On a sloped land, rhizomes should be planted in such a way that the buds should be come out on the upper side of the slope.

6.9. GUIDELINES FOR MANAGEMENT

Traditionally, bamboo has been referred to as minor forest produce. However, the status of bamboo has changed considerably and it is rapidly emerging as an important plant group in many forestry programmes. During the past few decades, several Asian countries have embarked on large - scale cultivation of economically important species. The important guidelines for raising and management of bamboos has been discussed here.

Although the raising of bamboo plantation by vegetative methods is found successful, however the availability of required propagating material found scarce. Seeds possess short period of viability and the procurement of seeds also difficult. Hence, the seedlings obtained from tissue culture methods can be used. The large sized polythene bags 20 cm x 30 cm are filled with clean soil, sand and manure in the ratio 2:1:1. About 15 to 20 plants should be planted in each polythene bag. The nursery is adequately irrigated and care should be taken to

avoid over saturation. Seedlings should be kept in polythene bags for one month. Nursery beds will be provided with a coconut thatch to protect the seedlings from direct sunlight.

Each polythene bag contains 15 to 20 seedlings. The number of rhizomes may vary from 4 to 5. These set of rhizomes should not be singled out (or) sorted out, but the entire thing in one polythene bag is planted in the field.

The seedlings will be removed from their polythene bags carefully and transplanted to 45 cm x 45 cm x 45 cm pits in the fields at a spacing of 6 m x 6 m. One weak prior planting, the pits should be treated with 0.01% aldrex and 0.05% bavistin to prevent termit and fungal attack respectively. The planting should be completed before the monsoon got fully set in.

To provide better initial growing environment to the seedlings, the upper halves of the pits were filled up with a mixture of 25 gram 15:15:15 N.P.K. fertilizer per pit, while lower halves were filled up with the original soil. Protection against damage by rodents, grazing and browsing animals is to be carried out. The profuse watering is done, but over watering should be avoided.

The transplanted seedlings produce rhizomes, which develop new rhizomes that produce lateral culms, which are the chief causatives for the total biomass yield. The number of culms developed from the rhizome totally constituted to a clump (Plate - 12, 13).

At a given site, the production, of new culms is dependent on the culms of the previous year, the degree of congestion and the clump age. The average annual recruitment of culm age. The average annual recruitment of

culm generally increased year after year. The culms produced during first year is shorter in length and smaller in diameter, but culms from subsequent years will be longer in length and bigger in diameter.

The rhizome development is not peripheral as generally believed. Rhizomes may develop in any direction and the culms may appear anywhere in the clump provided overhead light is available for the emergence of the culm. It is only in congested clumps that the new culms appear to grow at the periphery. The new culms can even be seen in the middle of the clump.

New bamboo culms will be produced each year. Older culms should therefore be harvested every year. Culms older than two years take little part in the growth of the new culms. Retention of culms older than two years, therefore not needed for the production of new culms. Culms older than three years are fully matured for the desired end use. The following rules should therefore be applied for getting high productivity of the desired quality of culms.

a) All bamboo culms three years older should be harvested

b) Harvesting should preparably be done each year

c) Where congestion has already set in the congested culms must be removed even if it leaves only the current year culms.

d) Where the young culms are twisted from the top they should be cut, so that new culms grow freely

e) No felling operations should be carried out from July to October

f) Mounding (or) heaping earth around the bamboo culms should be carried out after every felling of culms

g) Bamboo clump should in no case be clear felled. The clear felled clump generally degenerate into a bushy form.

The above mentioned siliviculture and management practices can be used as guidelines for taking up large scale plantation on suitable site.

CHAPTER - 7

GROWTH AND DEVELOPMENT

7.1. GROWTH OF SEEDLINGS

The seedling bamboo resembles a blade of grass. Seedlings should be watered daily and death does not appears to be due to onset of the dry season. Bamboos (the monocotyledons) have very different root system. The seedlings develops a underground rhizome system, which carries a dense mat of thin usually undivided adventitious roots, which show no secondary thickening and are replaced by new ones as they die off in the course of time. From the rhizome, in due course, culms of successively larger size are sent up.

7.2. DEVELOPMENT OF RHIZOME

A scaly rhizome (or) underground stem will be produced from the base of the seedling plant and after growing vertically downwards a short distance curves up again and appears as a small culm. Further rhizome sections will be develop in succession from the first and follow the same penetrating deeper into the soil till the optimum depth of about 0.5 m is reached and sending up successively larger culm. Full sized culms will be produced after 2 - 5 years depending on species and conditions. The rhizomes often branch two (or) more club shaped lengths each sending in a culm (or) culm bud developing from buds on a single older length. It appears to be unusual for culms to be produced from rhizome sections more than 2 (or) 3 seasons old growth accordingly it normally tends to be peripheral, but rhizomes sometimes grow towards the centre specially if conditions are unfavorable. In the species

in which the rhizomes extends some distance before sending up new culm, the culm themselves may well spacedout and individual plants often cannot be distinguished from their neighbourhood e.g. in *Melocanna baccifera*, but in many of the more important species notably *Dendrocalamus strictus* the rhizome section are short and culms remain close together in a clump.

7.3. CULM GROWTH AND DEVELOPMENT

There are three phases of growth and development of culm viz., culm elongation (first phase) (Plate - 3) which on nearing completion triggers thorn emergence (second phase) (Plate - 14) and finally leaf appearence (third phase) (Plate - 14). The first phase commences with "Komali" which means tender culm (30 to 40 cm high) completely covered by sheaths with no isternodes seen outside and looking funny like a foolscap Plate-15. This stage lasts for about ten days and growth will be extremely slow. After the initial period of slow growth the elongation will takes place in spurts of increasing rates and reaches the peak lasting a few days and then falls rapidly marked by leaf appearence, culm elongation is over in 70 to 90 days depending on the length of culm. The emergence of thorns (in *Bambusa bambos*) commences from the 25th to 50th day of "Komali" appearence and will be completed in about 135 days. Leaves appear on the 60 - 90th day and the culm becomes fully leafy in about 150 to 180 days. The supple culm hardens on account of silica deposition in the walls. It is December - January by the time all these biological consolidation will takes place in the next six months. In the coming June -July - August the cycle of vegetative activity resumes with the development of "daughter" rhizomes. Rarely even before the current - year - culm attains full development the rhizome buds develop pre

maturely but they fail very soon. Years bearing more sprouts (or) Komali (on-year) and those bearing fewer (off-year) usually occur alternately every year. While in a good sprouting year new culms are large in size, in a year when sprouts are less in number, the size of new does not become large. This, however, does not appear to be of a permanent hereditary nature, but it can be controlled by fertilizing and other means. All culms produced from the single seedling unit together constituted to a clump.

7.4. ANNUAL RECRUITMENT OF CULMS

The productivity of bamboos will be assessed by the number of new culms produced annually. At a given site, the production of new culms mostly depended on, the degree of congestion, clump age and rainfall of the previous year. In India, new culms generally appear during the rainy season. An unusual rain during the winter months may induce the emergence of new culms.

Bamboo seedlings (*Bambusa bambos*) were planted in 1987 at Kallipatty, (Plate - 16) Tamil Nadu, India. Almost all seedlings (250 seedlings ha-1) produced culms in 1988, the next year of plantation. Since then the culms were treated as 1 - year and recording of different growth measurement have been continued for nine years (Shanmugavel, 1995). The *Bambusa bambos* species produced only 5 culms per clump in the first year. The number of culms gradually increased in the subsequent years and became maximum (17 culms) in the 6th year of clump age. Number of culm production then slowly decreased from the 7th year and were only 6 in the 9th year of clump age (Table - 4). Similar results were also observed by Banik (1988) in four other Bambusa species, namely *Bambusa vulgaris, Bembusa balcooa, Bambusa*

longispiculata and *Bambusa tulda* and *Melocanna baccifera* at the Forest Research Institute, Bangladesh (Table - 5). Cumulative total culms produced in the clumps of all these *Bambusa* species upto to 6th year of age made crowded condition due to short (7 -12 cm) neck pachymorph rhizome system. This crowded and congested condition created a scarcity or room for the new emerging culms and also increased competition among them for survival. (Kondas, 1981, Banik, 1983; Shanmughavel, 1995). Probably due to this reason culm production subsequently decreased from the 6th year in the *Bambusa* species. Anonymous (1977) observed in a clump of *Bambusa vulgaris* planted in Dandeli, India that the culm production was higher upto the 4th year after planting and then decreased in the subsequent year (Table - 6). However, in the case of *Bambusa bambos* the culm production increased upto 10 years (Table - 7) (Kondas, 1981).

In *Melocanna baccifera* the average production of culms was 2.5 in the first and from third year the number increased rapidly to 12.5 . Culm production also rapidly increased in the subsequent years reaching 35.7 after the 10th year of clump age (Table - 3) unlike, other clump forming bamboos *M. baccifera* has underground pachymorph rhizomatous system with strongly elongated (1.0 - 1.5 m) neck (Banki, 1980). Owing to this rhizome nature the species produces culms at varying intervals in all directions forming a diffuse and open type of clump condition (Watanabe, 1986) which can accommodates the space required for the increased number of culm production in the subsequent years after plantation. Probably due to this reason the rate and pattern of clump girth expansion in *M. baccifera* are different from those of other Bambusa species. Othman (1992) reported that the annual

recruitment of culms was decreased from the third year clumps of *Gigantochloa scortechnii* at Forest Research Institute, Malaysia. *Gigantochloa scortechnii* plantation consists of 33.6%, 42.2% of 1, 2 and 3 year old culms after planting respectively (Table - 8).

7.5. CULM HEIGHT AND DIAMETER

Culms of all bamboo species complete their growth within 2 to 3 months after the emergence of sprouts from the ground, but their diameter and height do not increase after the growth is over (Mc Clure, 1967; Banik, 1980; Ueda, 1981, Shanmughavel, 1995). It has been observed that in all bamboo species that the culms emerged in the first year after plantation were short in length and narrow in diameter at breast height (Table - 4). Culm produced in subsequent years were distinctly taller and wider in diameter then those produced in the past years and such trend is continued upto 6 years in *Bambusa bambos* (Plate - 17). 5 - 6 years in *B. longispiculata* and *B. tulda* and 7 years in the case of *B. vulgaris* and *B. balcooa*. After these periods clumps of these *Bambusa* species did not produce any taller and wider culms in the subsequent years. Clumps of *Melocanna baccifera* produced taller as well as wider (with increased diameter) culms in the subsequent years of planting and the trend was distinctly rapid upto four years of age. Culms produced in the later years (upto 10 years of study) were also taller and wider but at a comparatively reduced rate. Similarly, culm diameter was also not much different in the subsequent years after the fourth year of clump age (Banik, 1988). Similar results were reported in other bamboos *Bambusa bambos* and *B. vulgaris* (Kondas, 1981) *Gigantochloa scortechnii* (Othman, 1992).

7.6. MONTHLY RECRUITMENT OF CULM

From the bamboo plantation, set of fifteen clumps were randomly selected from the sixth year plantation for the assessment of monthly, recruitment of culms (Shanmughavel, 1995). Every month, the number of newly sprouted culms and their survival were recorded. The observation continued for full one year. The monthly recruitment of culms for the year 1993 presented in Table - 9. It revealed that maximum recruitment of culms took place during September - November which was the monsoon season. An average of 17 culms were produced from one clump during 1993. However, their survival rate was reduced drastically due to white ants and other physiological causes. Monsoon dependency of the plantation was prominent, since the maximum recruitment of culms seems to be monsoon dependents rather than intermittant showers

7.7. DAILY HEIGHT GROWTH

In order to study the daily height growth of plantation bamboo from three hectare 15 clumps were selected at random from the sixth year plantation and identified with paint marking. Number of culms sprouting from the selected clumps were taken for growth measurements. In each clump, five newly sprouted culms were marked with paint, totalling 150 observations. On alternate days the height of each culm was measured and only after reaching 1.37 m height, the diameter at breast height (DBH) was recorded. All observations were made for the basal area girth, DBH and growth in height on all culms. In *Bambusa bambos*, culms reached their maximum height in about 4 - 5 months analogous to *Gigantochloa levis* and *G. ligulata* (Othman, 1992). Under cultivation, the average

daily height growth is approximately 30.0 cm at sixth year which might vary considerably between species depending on the soil conditions and mineral nutrition (Raghavan, 1964; Kondas, 1974). The daily height growth of *Bambusa bambos* are presented in Table - 10. The maximum growth per day (24 hours) comes to be found in the vigorous growing period. According to the records, the growth per day is 91.3 cm by *Bambusa bambos* observed at Kew Gardan in England (1855) and 88.0 cm by *Phyllostachys edulis* which shibata (1898) observed at Koishikawa Botanical Garden in Tokyo. Ueda (1981) recorded the growth 119 cm and 121 cm per day by *Phyllostachys edulis* and *Phyllostachys reticulata.* Such a remarkable growth could never be seen in any other plants.

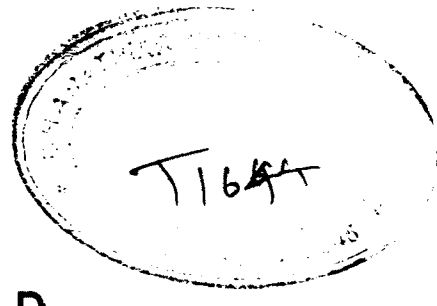
7.8. PATTERN OF BIOMASS ALLOCATION IN GROWING BAMBUSA BAMBOS

The pattern of biomass allocation was studied from the ten selected clumps from which young sprouted bamboo (culm) reached a height of 12 cm. At one week interval, these young bamboos were felled and their height was recorded. Each young bamboo after fully differentiated with culm, branch and leaves, the whole unit was felled and these components were separated individually. Their fresh weight was determined in the field and all the sub samples were brought to the laboratory filling in plastic bags. They were oven dried to remove all moisture at $103^0 \pm 2^0$ C to a constant weight. From moisture free oven dry weight of these samples, the dry weight of each three component and their total weight was calculated.

There was a significant increase in culm weight, as it attained maturity. There was a 12 fold increase in culm weight from its initial sprouting (0.150 g) to month

(1.850 kg/culm). This weight increased as the branches and leaves began to develop. The total oven dry weight of the culm with its components from its sprouting is given in Table - 11. There was considerable variation between dry weight of sample culm and their components. In young sprout the moisture loss was 60 - 70% up to the development of branch bud. After initiation of leaves, the moisture content was 50 - 60%. Later the moisture ranged from 33 - 45%.

The biomass allocation of the components in growing *Bambusa bambos* is given in Table - 12. It may be noted that, 80 - 85% of biomass was allocated to culm, 15 - 20% of branch and only 1% was found in leaves.



CHAPTER - 8

BIOMASS AND YIELD

8.1. Biomass production

In plantation raised at an espacement of 5 m x 5 m by seedlings, the clump formation generally takes places in the 3rd year or 4th year depending on the soil, rainfall and its distribution. By about 6th year, exploitable full grown culms are produced. On an average, 5 new culms are produced per year per clump and there are about 275 to 300 productive clumps per hectare. The size of the biggest culm, however, does not exceed 5 cm diameter at the second internode from the base and 6 - 8 meter in length, weighing about 2 to 2 1/2 kg (green). It is observed that systematic and commercial working of the plantation could be started from the 8th year. It is expected that on a 3 year cycle, a good plantation may yield about 3 - 4 tonnes of bamboo per hectare at the first cut, 5 - 6 tonnes at all the second cut and 8 tonnes from the third cut. Assuming on a conservative basis a life cycle of 32 years only, when gregarious flowering sets in and the clump dies, in all 8 cuttings can be made with a final clear felling after gregarious flowering, which is expected to yield about 15 - 16 tonnes per hectare. Thus the total expected yield per hectare is about 70 - 74 tonnes over the entire life of plantation (Suri & Chauhan, 1984). However, Shanmughavel (1995) observed that the plantation raised at an espacement of 6 m x 6m by seedlings at Kallipatty, District of Periyar, Tamil Nadu, India, the clump formation takes places in the first year, gradually increased in the subsequent years to 9, 14, 15, 16 and 17 in 2, 3, 4, 5 and 6 years respectively. The size of the biggest culm, however,

does not exceed 8.5 cm diameter at breast height and 28 to 29 meter in length, weighing about 68 kg (green). The organic matter productivity of *Bambusa bambos* of 1 to 9 years presented in Table 13 - 21. The mean annual biomass accumulation increased with stand age. But the data on mean periodic increment and net primary production showed that the rate of biomass accumulation was highest at the age of 5th year, during which a peak of 124.08 $t^{-1}/ha^{-1}/yr^{-1}$ in net primary production was obtained (Table - 22). The productivity of plantation on unit area basis is presented in Table - 23.

Chaturvedi and Bhatia (1993) of Tata Energy Research Institute (TERI) started working in the area of reclamation of saline and alkaline lands in 1986 - 87. The centre was established with the main objective of developing such planting models that could identify optimum mix of species for similar site conditions, be easily applicable to private farmlands and also provide remunerative returns to farmers. They are planting *Dendrocalamus strictus* in combination with *Acacia nilotica* and *Casuarina equisetifolia* during 1987. Bamboo clumps raised from seedlings and planted in July 1987, established by 1989. The growth statistics given in Table - 24 clearly show that emergence of new culms (the actual number) is directly related to age of the clump. This indicates a healthy growth trend. The culms that emerged in 1989 matured and were ready for harvest by 1991. In the period between 1987 and 1989, there was emergence of new culms. However, as this was the establishment phase of the bamboos, the growth was taking place mainly in the rhizome under ground, resulting in emergence of culms with very small diameters. These culms have been removed as and when required (under culture operations) and have not been included for growth yield estimations. The net yield

from these mixed plantations is presented in Table - 25. It reveales that the air dry weight decreased from 1992 to 1994. However, they reported that, the plantation successfully checked soil - erosion and soil - alkalinity.

Othman (1992) investigated the culm composition and above ground biomass of *Gigantochloa scortechnii* stands at Forest Research Institute, Malaysia. It revealed that, 422 clumps per hectare (with the average of 19 culms/ clump) in natural stand compared with 400 clumps per hectare (25.6 culms per clump) to those in plantation consists of 33.6%, 42.2% of one, two and three year old culms after planting respectively. The above ground biomass of *G. scortechnii* in natural stand was 71.9 t/ha-1 than that of the plantation which was about 36.2 t/ha-1. The dry matter density of *G. scortechnii* i.e. the above ground biomass of bamboo divided by its average height, was found to be 0.55 kg/m3. In natural stand only 4.7% of the culms was categorized as good culm suitable to be harvested while none in the 3 year old plantation. The above ground biomass of *G. scortechnii* is presented in Table - 26.

In bamboo, generally the above ground biomass as well as dry weight of biomass components increased concomitant with DBH (Diameter at Breast Height) and height of the culm with contributes a major share to the total biomass. Aging improves above ground biomass which is accumulated maximum at the age of six. In natural forests the culm weight of *Phyllostachys edulis, Phyllostachys reticulata*, varied between 13 and 44 kg/culm respectively and their height and diameter to age also was lesser than their counterparts of plantation stands. The culm fresh weight of *Dendrocalamus strictus, Bambusa bambos* and *Melocanna baccifera* tends to be more than *Phyllostachys*

species, but with same diameter. Since, the culm height of the former three species are taller, their fresh weight with the same diameter and thick walls tend to be heavier than *Phyllostachys* species (Ueda, 1960). In comparison with above three species under natural forests bamboo under plantations showed 19 to 85% heavier culm weight.

With regard to the percentage contribution of biomass components to the above ground biomass (Table - 27) the plantation age was an important factor. The percentage contribution of leaf (7% to 1%) decreased with increasing age. This perhaps reflect that leaf formation seizes with age and growth. The leaves are deciduous. When they fall off from the base of culms and branches new ones replace without any additional number. No definite trend was observed in case of branch. They are produced as the culm elongates in height and the total amount of branches appear to be fixed with the growth of the culm (Shanmughavel, 1995). The percentage contribution of rhizome to grand total biomass correlates with leaf. Several plantation crops such as *Eucalyptus teriticornis* (Singh and Sharma, 1976) *E. hybrid* (George, 1977) *E. globulus* (Negi *et al.*, 1984 and Tandon *et al.*, 1988; Pandey *et al.*, 1989 and George and Varghese, 1990) fall in line with bamboo in these regards.

8.1.1. Total biomass

Compared with biomass measurements the annual yield of air dry bamboo per ha. of 3 - 4 year old plantation was found to be 6 - 7 t. ha-1 for *Bambusa vulgaris* and *Gigantochloa aspera* (Chinte, 1965). The above ground biomass of *Gigantochloa scortechnii* from Malaysia was 71.9 t/ha in natural stand and 36.36 t/ha in a 3 year old plantation (Othman, 1992). This is lower than 3

year old plantation stand (47.48 t/ha) of Kallipatty, Tamil Nadu, India (Shanmughavel, 1995). Compared with other fast growing tree species 8.6 t/ha in 4 year old *Eucalyptus globulus* (Cromer *et al.*, 1976), 47 t/ha in 5 year old *Leucaena leucocephala* (Pandey et al., 1989) and 87 t/ha in six year old *Pinus caribaea* (Madgwick *et al.*, 1977), the present estimates are found to be 7 to 30% higher (Shanmughavel, 1995).

8.1.2. Below ground and above ground ratio

The below ground and above ground biomass ratio between 1 year old and 6 year old plantation varies from 69% to 4% (Shanmughavel, 1995) One year old younger plants develop vast lateral roots from their below ground parts and provide the much needed water and nutrients to the plants. In order plants (6 year old) the aerial parts were more developed than the under ground parts. This ratio may vary with plant species and their age. In a 8 year old plantation of *Populus deltoides* the ratio was 1% (Kaul *et al.*, 1983). This ratio was 30% in *Tectona grandis* (Prasad, 1974) and 28% in *Terminalia tomentosa* among 15 - 20 year old plants of natural dry deciduous teak forest. The 5 year old *Eucalyptus camaldulensis* (Prasad et al., 1984). All plantation and forest species tend towards a similar direction, since all the plants are ultimately depending on the underground biomass for water and mineral nutrients.

8.2. BIOCHEMICAL CHARACTERISTICS OF PLANTATION BAMBOO LEAF (*BAMBUSA BAMBOS*) WITH REFERENCE TO ORGANIC PRODUCTIVITY

The significance of chlorophyll content in characterizing the productive potential of various crops was repeatedly stressed (Suryanarayanan, 1978; Hegde &

Bawachker, 1983; Tyagi and Malik, 1988 and Malik *et al.*, 1993). The entire biomass productivity depends ultimately on the photosynthetic efficiency of the leaf. The bamboo leaf revealed kranz anatomy apparently proving a tropical grass and its chlorophyll, chlorophyll a, chlorophyll b, a, b ratio, carbohydrates and starch were inversely proportional with age (Table - 28) (Shanmughavel *et al.*, 1995). The results showed high correlation between the biomass productivity and chlorophyll content analogous to mango cultivars (Malik et al., 1993). The total above ground biomass increased 6.9 times from 1 year to 2 year. Further increase was in the order of 5.0, 2.5, 1.8 and 1.2 times from 2nd, 3rd, 4th and 5th year respectively. It revealed that, the total above ground biomass increase decreased with the age of bamboo. It may be due to gradual decrease in all the biochemical constituents of bamboo leaf with increase in all the biochemical constituents of bamboo leaf with increasing ratio was decreased with age of the bamboo, the Table depicts the gradual increasing trend, which may be due to higher recruitment of bamboo culms from first year (1250 culms/ha) to sixth year (4250 culms/ ha).

The biochemical constituents of natural (wild) bamboo leaf was 34% higher than plantation crop revealing that under natural stand the constituents were metabolished slowly, resulting lower turn over of biomass. The organic productivity of bamboos from plantation crop (Shanmughavel and Francis, 1995) was higher than natural forests bamboo (Chinte, 1965 and Othman, 1992).

8.3. ECONOMIC ANALYSIS

Bamboo is used nearly in every aspect of daily life. As per available statistics, bamboo forests occupy an

area of about 10,300 KM^2 in India and annual production is about 4.5 million tonnes - (Gaur 1987). Although reports on the status of research, inventory production and utilization aspects of Indian bamboos are recorded in literature, these are inadequate. The research on production and marketing will indicate the appropriate means for improving the capabilities of the rural people in producing bamboo based products.

Yields of bamboo varies widely in different climatic zones. It also depends on the density of the crop. Therefore, its financial viability is dependent on climatic, silvicultural practices adopted and market conditions. It is necessary to quantify - some of the intangible benefits of bamboo forests - in economic analysis. Bamboo forests are very effective in preventing soil erosion and also improve the water retention capacity of the soil. Bamboo forests are also known to improve barren and semiarid lands. Thus, soil fertility is preserved, water run-off controlled and siltation of water courses and reservoir drastically dimnished by bamboos.

In some of the areas, particularly aridsoils economic analysis of bamboo plantations at market prices may clearly indicate the non-profitability of the project. Some of the intangible benefits are, however, difficult to quantify. It is therefore, reasonable to assume that if their unaccounted contribution is considered, it may place the bamboo plantations within the limits of the socially profitable undertakings.

8.3.1. Bambusa bambos

The cost of maintenance and expenditure incurred on extraction of bamboo and expenditure incurred on extraction of bamboo for six year old *Bambusa bambos*

plantations at Kallipatty, Tamil Nadu is given Table - 29. The cost of raising the entire plantation and maintaining it until 6 year maturity was Rs.. 44180. The expenditure incurred on extraction of the bamboo was Rs. 108,125. The local revenue realised by the sale of extracted bamboo is Rs. 231,500 (Shanmughavel and Francis 1996).

On the whole 10,750 culms (including 4, 5, 6 age groups) were obtained from 250 clumps per hectare. Along with the exploitation, a cleaning of the clump was also done to facilitate to development of new culms. The thorns obtained during extraction are also sold for what they are worth. The main principal followed were that a minimum of six mature culms would be left in each clump and all tender bamboos less than a year old would be left without cutting.

From the financial results obtained it could be seen that a net surplus of Rs. 79,195 could be obtained from one hectare of plantation - after five years. From the general observations made in the plantation of fresh culm production, we can expect more yield in the following felling cycle and prices of bamboo remaining the same (likely to increase) the financial return also can be expected to be as good.

The details of simple economic analysis of cost and benefit of *Bambusa bambos* plantations were presented in Table - 30. It can be concluded that, the establishment of *Bambusa bambos* plantation is not profitable at the end of three years. However after this period, it is noticed that cost benefit ratio (B/C) exceed 1.0, showed very good financial results.

8.3.2. *Dendrocalamus strictus*

The report of the commercial exploitation of

Dendrocalamus strictus - an economical analysis by Reddy *et al.* (1990) is given below.

8.3.3. EXPENDITURE

The cost incurred for raising one hectare of plantation and maintaining the same for five years is estimated to be Rs. 30,000/-. Considering the flowering cycle once is 30 to 40 years, bamboo can be conveniently harvested for a minimum of 25 years. The cost expended on the maintenance of plantations from 6th year to 30th year (i.e. total of 25 years) will come to about Rs. 1,17,500. The pooled cost expended for 30 years will be around Rs. 1,47,500/- (Table - 31).

8.3.4. INCOME

From the data it is evident that on an average to clums per clump would be available for harvesting annually. Thus with total population density of 625 per ha. following 4 x 4 m spacing will yield 6250 culm per ha. annually. The annual income accrued by 5000 culm will be Rs. 35,000 per ha. with selling of Rs. 7 per culm making allowance for damages of about 20%. Thus the total income accrued for 30 years would be Rs. 8,75,000/-. By incurring total expenditure of Rs. 30,000/- per ha. till 6th year, the annual net income would be Rs. 35,000/- per ha. which can be extended till clumps flower.

Balaji (1992) reported that, bamboo grown Seerkazhi of Thanjavur District at 7 m x 7 m espacement at the initial cost of Rs. 2000/- acre, can yield from 100 - 150 clumps upto Rs. 20,000/- per acre once in two years from 7th year onwards.

Torane et al. (1994) studied the estimation of cost

of establishment, cost of production, income and economic viability of bamboo plantation in Ratnagiri District, Maharastra. It revealed that per hectare total establishment cost was Rs. 12280. The per hactare total cost of cultivation was Rs. 12054 and income Rs. 28114 resulting in a net income of Rs. 16060. The pay-back period was found to be 5 years, 5 1/2 years and 6 years at 14%, 16% and 18% discount rate respectively. It means that as discounting rate increases, pay-back period also increases. The profitability index and benefit-cost ratio with three discounting rates are greater than unity. Net present value is positive and internal rate of return is higher than prevailing borrowing interest rate. The pay-back period is quite short. Bamboo production is quite profitable and hence investment in bamboo in worthwhile.

Economics of bamboo plantations in Uttar Pradesh was workedout by Chaturvedi (1986). According to him, the benefit cost (B/C) ratio 1:7 at 14.5% rate of discount. In another study Tewari (1981) has tested the economic parameters on costs and benefits data of one hectare bamboo plantation in Madhya Pradesh and found benefit cost ratio (b/c) as 1:85 at 14% discount rate. Shanmughavel and Francis (1993) reported the cost benefit ratio (B/C) as 1.51 at 12% discount rate and 1:52 at 14 - 16% discount rate.

In conclusion, the result from the studies on culm production pattern and marketing of bamboo product can be used as guidelines for the improvement of bamboo resource utilization as well as for improvement of income distribution.

CHAPTER - 9

FELLING CYCLE AND FERTILIZER APPLICATION

9.1. FELLING CYCLE

Bamboo is considered to be unique raw material from the point of view of its quick growth, easy availability, strightness, smoothers etc. It is used for various purposes such as construction of rural houses, ladders, mats, baskets, pipes, handicrafts etc. But the largest demand is for the manufacture of paper. During the last few decades, it has become a major source of raw material has an installed capacity of 0.3 million mt of newsprint pulp, 0.196 million mt of paper grade pulp, covering 316 small, medium and big paper mills and produced about 2.75 - million metric tonnes of paper and paper board during the year 1992. (Adkoli 1992).

The industry is presently facing problems of non-availability of suitable fibrous raw materials in adequate quantity to meet its requirements. The supply of bamboo, so far the main raw material for the industry has been dwindling in the recent years. Sustained availability can be ensured only elaborate bamboo cultivation (Shanmughavel, 1995). Still bamboo accounts for the 60 per cent of the fibrous raw material requirement of the industry. In order to meet the present and future requirement of the paper industry, efforts are needed not only to improve productivity, but also to use the existing bamboo resources - judiciously and efficiently (Razzaque *et al* 1981). During the extraction of bamboo from the forest no definite cutting age is maintained. Rather bamboos of different age groups extracted indiscriminately. As a result pulping of a mixture

of bamboos of different age groups may result in heterogeneous cooking, producing inferior quality of pulp. To overcome these problems, several studies have been undertaken. (*Melocanna baccifera, Oxytenanthera nigrociliata, Dendrocalamus longispathus, Bambusa tulda, Neohouzeau dulloa*, (Razzaque et al 1981), *Melocanna baccifera* (Bose et al. 1988), *Dendrocalamus strictus* (Maheswari and Satpathy 1988), *Gigantochloa scortechnii* (Kasim et al 1992) *Bambusa bambos* (Shanmughavel, 1995) to observe the optimum age for felling the plantation bamboo for pulp and paper making and other uses. This will help to determine an optimum cutting cycle for the species under investigation. The salient features of studies are pointed here Shanmughavel (1995).

1. Fibre and pulp qualitative characters were almost equal among all ages of bamboos (Table 32 - 34). Their quantity difference was dependent on the total biomass production, which is related to the age of the plantation, indicating that age is not a criteria for qualitative fibre harvest.

2. With an increase in age, cellulose, lignin, pentosans, 1% NaoH solubles, Alcohol - benzene solubles, cold and hot water solubles, ash contents also increase (Table - 35).

3. It was observed that with increasing age active alkali requirement to get a fixed kappa number increases. Total pulp yield also increase with increase in age of culm. (Table - 36).

4. The physical and strength properties of both unbleached and bleached pulp increase in age of bamboo (Table 37 - 40).

5. Based on the percent pulp yield, if stationary digester is charged with 20 tonnes of bamboo chips with 19 - 24% alkali, the output would be 8.7 to 9.0 tonnes of pulp.

The study reveals that in plantation bamboo, through no appreciable change in chemical composition of pulps could be monitored with increasing age, these bamboo species may attain their maturity during the first year of growth. Hence one to six year old culms can be used raw material for pulping. However in order to get a higher annual recruitment of culms in subsequent years it is recommended that 36 months cutting cycle is ideally suited for pulping purposes.

Bose et al. (1988) suggested a cutting cycle of 21 months for *Melocanna baccifera* from the point of yield gain. Biennial felling cycle has also been observed to give maximum yield and superior quality in case of *Denodrocalamus strictus*. From management point of view biennial felling cycle does not cause any serious difficulties (Mohan, 1931). Youdi *et al.* (1985) also concluded for ten bamboo species that the bamboo should not be older than 36 months for chemical utilization if practices of cultivation and rotation are considered. Shanmughavel (1995) recommended that, 36 month cutting cycle is ideally suitable for pulping purpose.

From the above studies it may be concluded that 36 month felling cycle is ideal for plantation bamboo for all purposes.

9.2. FERTILIZER APPLICATION

The bamboo consumes a lot of inorganic nutrients in order to grow and propagate. These mineral

salts are supplied naturally through the soil. Bamboo grove where no fertilizing, the culms can be harvested to a limited amount corresponding to the natural supplies of nutrients. Once the amount of harvest exceeds the level, however, fertilization will become necessary to make up for the deficit caused by the increment of harvest. Ueda (1960) conducted some experiments on the chemical analysis of culms and rhizomes with regard to the mineral nutrients and the quantities that the bamboo requires and on the time and place of fertilizing. The following shows an outline of the results.

9.2.1. Three elements (Nitrogen, Phosphorus and Potassium)

The fertilizing tests were conducted at the groves of *Phyllostachys reticulata* and *Pleioblastus pubescens* (Pot test). Nitrogen is the element most required by bamboo, followed by potassium and phosphate. It was found that these three elements are most effective when used together. The total fresh weight of culms, branches and leaves of *Pleioblastus pubescens* decreased to 0.8 times at non - N plots, to 1.5 times at non - K plots. and to 2.9 times at 3 - element plot for the non fertilized plots. The total fresh weight of rhizomes at the three - element plots also increased to 2.5 times even in non - fertilized plots. It was further detected by chemical analysis of culms and rhizomes that the amount of K2O absorption - is higher as compared with those of N and P2 O5 (Table - 41). The total product of new culms of *Phyllostachys reticulata* grove in one year suggests the necessity of applying the three elements mixture (Table 42). The experiment at the *Phyllostachys reticulata* groves shows the results; 1 represents the product of non-fertilized plots (900 kg products per 0, 1 ha) then 1.3, 1.4 and 1.6 (about 1400 kg

per 0.1 ha) times at non-K plots, non-P plots and 3 element plots respectively.

8.2.2. Amount of the three elements to be applied

The amount and proportion of the three elements to be applied to the plantation was investigated by various workers. Some important results are discussed here.

Patil and Patil (1988) carried out investigations to determine the effect of varying spacing and fertility levels on the growth and nitrogen uptake of bamboo. A field experiment was conducted on the bamboo, Dendrocalamus strictus (Roxb) Nees with three spacing, 1 x 1, 2 x 2, 3 x 3 m and two fertilizer levels : 100 + 50 +50 kg and 200 + 100 +100 kg NPK/ha per year on clayey loam soil. In the closer spacing treatment (1 x 1 m) 9.9 culms per clump was obtained as compared to 6.5 and 6.2 in the medium (2 x 2 m) and wider (3 x 3 m) spacing treatments, respectively at 572 days after planting. The closer spacing resulted in a higher leaf area (LA) per clump, leaf area index (LAI), leaf area duration (LAD), rate of dry matter production (DM) and crop growth rate (CGR), which were instrumentel in increasing total dry matter (TDM) production. TDM increased from 4 tonnes/ha. in the control to 12.5 tonnes/ha. with an application of 100 + 50 + 50 kg NPK/ha. per year.

In another study Thomas (1988) conducted an A 33 factorial experiment with N, P and K on the growth of *Bambusa bambos* seedlings in pots. N was applied to 20, 40 and 60 g P at 9, 18 and 27g and K at 25, 50 and 75g per pot. The result indicate that N, P, and K at all levels and combinations increased the biomass production significantly over the control except for N3 P3 K3 which showed a retarding effect. Among levels 1, 2 and 3, a

significant difference was observed only in the case of N and specifically in shoot and rhizome production. Interaction between N and P was significant in the production of leaf, shoot, root and rhizome while K interacted with N, P and NP in the production of shoots. N was found to be the most important element for enhancing biomass production, while P was effective in combination with N, K exerted only a minimum influence. N2 P3 K1 was selected as the best treatment combination through ranking of the treatments.

Fertilization experiments were conducted on *Thyrsostachys siamensis, Dendrocalamus asper, Bambusa* sp. and *D. strictus* in three year old plantation at Dong - larn in Kohn Kaen, Thailand (Suwannapinunt and Thaiutsa, 1988) The randomized block design with four treatments was used in these experiments. The treatments were different fertilization rates of 15-15-15 NPK fertilizer at 0, 100, 200 and 300 kg/ha. The results showed that 100 kg/ha. of fertilizer was sufficient for increasing the production of *Thyrsostachys siamensis, Dendrocalamus asper* and *Bambusa* sp. However, for *Dendrocalamus strictus*, 200 kg/ha of fertilizer was found to be necessary.

Fu Maoyi (1988) carried out fertilizer trials in stands of *Phyllostachys pubescens* in the South-east part of China. A total of 40 plots were laid out, each measuring 400 m2. The fertilizer used were compounds of N, P, K, and Si. Results showed that spring application in furrows at 375 kg/ha. gave a yield of 7870 kg of culms.

Shanmughavel (1995) reported that 200 kg ha-1 of 15-15-15 NPK fertilizer was sufficient for increasing the production of *Bambusa bambos* at Kallipatty, Tamil Nadu.

9.2.3. Effect of the various kind of nitrogen fertilizers

According to the experiment (Ueda, 1960), the production of new culms in the *Phyllostachys reticulata* grove is remarkably increased after every application of nitrogen fertilizers. The difference of the effect of fertilizer. The kinds of fertilizer used are solid fertilizer, urea, ammonium chloride, calcium nitrogen, ammonium nitrate, ammonium sulphate, barnyard mannure and night soil.

9.2.4. Other elements (Silicate)

Silicate (SiO2) is contained roughly more than 5.0% in the leaves, about 2.0% in the branches, about 0.4% in the culm and about 0.5% in the rhizome. SiO2 is effect in increasing the culm production. The leaves must be left in the grove after cutting off the branches at the harvesting. Because silicate is effective in increasing the culm production.

9.2.5. Season of fertilizer application

In the species that thrive by extending its rhizomes annually, the rhizomes produce new culms in a great number. Therefore, fertilizing is more effective if it is spread on the near place of young mature bamboos. Yet it is natural that the fertilizing effect should appear close to the site of application in the case of the clump forming species.

The application may be done anytime if the fertilizer of slow effect is used. In the case when a fertilizer of rapid effect is used, the application to be done about a month in advance of each season of growth, so that the effect occurs at the season of sprouting and rhizome growth (Ueda, 1960). Shanmughavel (1995) in his studies on effect of fertilization in the month of February, March and observed the general effect on culm growth within the same year.

CHAPTER - 10

INTRODUCTION IN SOCIAL FORESTRY

Bamboo is one of the most important multipurpose species and therefore, it is being introduced in a large scale under various programmes of social forestry. It is a domestic orborescent grass and villagers like to plant it in home gardens, around wells, compounds and in the agricultural fields. Almost every part of the bamboo finds some use. The culm has high market value and is used as building material, paper pulp resource, scaffoldings, fishing rods, weaving material, agricultural implements, parquet manufacture and as water conduits. Leaves of several species of bamboo are utilized as fodder during scarcity. The thorny branches are used as fencing material.

The bamboo is highly versatile. It is capable of growing in a variety of soils derived from different parent rocks, within its climatic habits. However, each species of bamboo has its own optimum site and soil conditions and rarely occur in mixture (or) in close association. The bamboo has been planted on a large scale along road and canals. It is also planted in degraded forest areas particularly near habitations. This can also be planted on agricultural fields and homestead plantations.

In social forestry programmes bamboo has been grown mainly in the following systems.

10.1) Strip plantation

10.2) Community Forestry Programme

10.3) Agroforestry plantation

10.4) Rehabilitation of degraded forest

10.5) Reclamation of wastelands

10.1. STRIP PLANTATION

The strip plantations along road, canal and agricultural fields combine, three recognised social forestry aspects viz. protection, community and subsistence forestry. They offer physical protection to the land resource, in that they not only conserve topography, soil, water, air and fertility, but also provide shade and amelioration of surrounding environment. Their existence provides protective barrier to adjoining cultivated fields. They resist and prevent the effects of high velocity winds and thereby avoid losses due to the detrimental effects of intense heat, light, wind velocity and abrasive and chemical effects of air pollutants. They meet the immediate requirement of the agricultural population of small timber, fuel and fodder and cater to grazing.

Roadside strips, (Plate 18, 19) through state government owned land resource, can be fully deployed for commercial purposes. Managerial limitation render the strip resource ineffective for sustained commercial production. The management problem further deepens due to variable site conditions. Soil characteristics in particular, vary greatly within a short length affecting the uniform growth of the bamboo species under the circumstances create problem. Road side strips are common property resources and can be effectively utilised for the production on a sustainable basis only when bamboo vegetation is grown with the active participation of local population. People's

participation can be achieved provided the right species is selected and people have sharing benefits. Production and influential benefits would naturally reach the community. Versatile bamboo readily meets the acceptance of the people and is adopted to varying soil conditions.

Bamboo is the fastest growing species attaining harvestable maturity in a brief spell of three years. The rural poor are the principal users of bamboo, using many time more material than the pulp and paper industries. The easy availability of bamboos, can help provide part time (or) seasonal employment in its processing for villages women. Bamboo are used for manufacture of large number of value added goods handicrafts, by the rural people. The growth in strip plantation is encouraging and support the productive aspects achieved through strip planting under social forestry programme.

The common practice of strip plantation is to prepare deep pits usually 0.6 x 0.6 m at a spacing of 4 meters and 6 - 8 months-old seedlings are planted in these pits. The achievements pertaining to strip plantations, particularly in respect of different states are not available. Bamboo has been planted along canal sides in several parts of Tamil Nadu. Observations on growth of the species planted on canal side in Tamil Nadu indicate that bamboo is one of the most suitable species for canal side plantation (Plate - 20).

10.2. COMMUNITY FORESTRY PROGRAMME

Bamboos for community forestry programme was suggested by Shanmughavel (1995). Community forestry programmes are based on growing bamboo on public (or) Community land contrary to private farms. The degree of local participation in planting and looking after the tree

varies. What all community programmes have in common, is that they are intended to provide benefits which are shared by the community as a whole.

The most common type of community forestry programmes is that in which the forest department takes on the responsibility for carrying out the planting. Inputs such as fertilizers and seedlings are provided without any outlay by the community. The engagement of the local community in the implementation of schemes of this type is largely passive and is normally restricted to the provision of hired labour for planting and an agreement to co-operate in protecting the plantation.

Other programmes rely on a much higher level of community participation and control. They are generally designed to use land, which is under direct community ownership (or) they can take place on state lands, which have been specially designated for community control. The main responsibility for planting and looking after the trees is taken by community itself and the role of the promoting agency is primarily a catalytic one.

Community programmes can use both commercial and non-commercial incentives as a way of stimulating local participation. In all cases, the key to success lies in persuading local people that the programme is in their interests such that the benefits they are promised are securely guaranteed.

10.2.1. Degree of local participation

As discussed earlier, the aim of community forestry programmes are to regenerate the degraded forests and barren lands by planting bamboo.

10.2.2. Local institutions

Community bamboo growing programmes are crucially dependent upon the active collaboration of village councils, community groups (or) other local institutions. Programme planning must therefore be based upon a clear affairs, their potential for realising (or) thwarting the aims of the programme. The village community groups should be trained (or) giving proper instructions about the growing of bamboo in the barren land by the specialists in the field. While selecting the village community groups, preference will be given only to the educated unemployed youths.

10.2.3. Land allocation

Maximum 25 ha. area of degraded/barren forest land is to be allocated at a time to each participating village group. In future, more land can be allocated if the work of the participating village committee is found encouraging.

10.2.4. Procedure of working

After collaborative micro planning a need based management plan will be drawn up. The forest department will assist the village committee to establish joint protection and management systems.

10.2.5. Requirements / rule of working

Order requires participating village committees to protect the allocated land against non-forestry use, encroachment, grazing, illicit felling and wildlife. Land in no case is to be allocated to individuals and ownership of the land shall remain with the Government. It is also required to execute an agreement bond between forest officials and the participating village committee.

10.2.6. Resource sharing

Entire bamboos obtained from community forestry programmes will go to members of the participating village committee. At the time of harvest prescribed in the management plan, after deducting the government expenditure, 60% share of net income will go to members of the participating village committee and 40% share to state exchequer. Participating village committee will again invest atleast 50% of this income in plantation activities.

10.2.7. Monitoring of works

A supervisory committee is to be constituted to monitor the development, protection and management works of the community forestry. Members of the committee will include respective district officer, a range officer and a representative of village committee members.

10.3. LIMITATIONS

10.3.1. The problem of land use conflicts

Obtaining the necessary land for tree growing is undoubtedly one of the major stumbling in programmes of this type. Community land is frequently scarce (or) is being used for a variety of other purposes. Agreement to dedicate it to tree growing can be very difficult to achieve.

10.3.2. Lack of identity of interests

Few communities have a genuine identity of interest among all their members. Practical experience has shown that this can cause a number of severe problems with community programmes, where communities are rigidly stratified along social, economic (or) religious lines, the

barriers to communal action can be partially difficult to overcome.

10.3.3. Scope for community forestry

The interest complexity of community forestry programmes, with their needs to compromise and reconciliation of opposing interests, means that they will always require a great deal of careful preparation and negotiation. This demands a high level of trust and co-operation between the community and the promoting agency which can, itself take a long time to create.

10.4. AGROFORESTRY PLANTATION

Bamboo is basically a household species and is the best friend of the farmers. It can be grown around houses, wells, compounds, on farm lands and other available places in the holdings. It is grown as homestead plantations because every part of this finds one use (or) other by the farmers. Agroforestry is a system by which agricultural crops can be grown in association with tree crops. Any agro forestry model should take into consideration, competition for light, space, water and nutrients between the tree crop and agricultural crop. Hence the tree crop selected should be compatible to the agricultural crop.

Floristic characters can also be used for classification of agroforestry system. For defining agroforestry systems on the species composition, it is necessary to have an inventory of all existing systems along with their component plant species. Some of the known combination parts of the country are as follows :

Region/Area In India	Agricultural components	Forestry Component
Central region	wheat, rice maize jowar, bajra, pulses oil seeds etc.	Bamboos of different species
Southern region	Rice, tobacco chillies sugar cane	*Dendrocalamus hamiltonii*
Northeastern region	Paddy	*Dendrocalamus hamiltonii*

Source : Dwivedi, 1994

Seshadri (1985) conducted three field studies during three different seasons during 1979 - 80 to explore the feasibility of raising soybean as an intercrop with bamboo (*Dendrocalamus strictus*). The intercrop was raised under irrigation. For comparison a sole crop soybean was also raised. The influence of the vigour of the bamboo clumps as well as response to three levels of P application (0, 100 & 200 kg P2 O5 /ha.) by the soybean as an intercrop of bamboo during the first six years is technically feasible and economically viable and also reported that the period of intercropping can be extended further in wider spacing of the bamboo culms and the judicious manipulation of the bamboo canopy.

Balaji (1991) reported that, the scope for bamboo in agroforestry is very wide because of the uncertain weather condition and increasing cost of labour involved in agriculture these days, even small (or) marginal farmer can get substantial income from Rs. 800 - 1000/- Once in 3

years from just one clump of bamboo planted with agricultural crop.

Agro forestry systems will not only help the farmer in getting better returns from his land but also provide tree in the rural areas that can check wind, erosion, conserve the precious top-soil and water and ameliorate the immediate environment in the rural areas.

10.5. BAMBOO WITH HORTICULTURE CROPS

An investigation is carried out to assess the performance of a systematically planted bamboo crop with that of traditional horticultural crops like mango, cashewnut, jack fruit, kokum and rubber in the Kunkan region. Bamboo is reported to be the most profitable among the crops studied and cashew & mango are ranked next to bamboo (Wagh and Rajput, 1991).

10.6. REHABILITATION OF DEGRADED FOREST

Total forest area of the country is reported to be about 75 million ha. According to recent satellite imagery, dense forest occupies an area of only 37.8 million hectare (FSI, 1989). The remaining area consists of degraded forest, where density of the trees is less then 40 per cent. The areas neither provide timber (or) firewood nor the ecological security. The programme of rehabilitation of degraded forest aims to restock these areas and improve their productivity. The process of rehabilitation includes tending of natural regeneration supplementing it with plantation of socially desirable species. Bamboo has been planted on a large scale in several states under rehabilitation of degraded forest programme. i.e. afforestation (Plate 21).

10.7. AFFORESTATION

Bamboo is a favoured species in the national afforestation programes as being a marvelous substitute of timber towards meeting the Industrial and rural requirements, checking erosion, conserving soil and moisture. Rehabilitation of degraded forest area is afforestation of degraded forests with a view to meeting the requirements of fuelwood and fodder of the local population. Here the management usually remains with the forest department. The afforestation programmes executed earlier, involved species which were not important for their fuelwood and fodder values. Invariably the species were such that were required by the industry. A quantum jump can be seen in the afforestation activity from the sixth year plan onwards (Table - 43).

It can be seen from the Table - 43, that although increasing emphasis was given to afforestation during the first to the fourth five year plans (1951 - 74), schemes which could meet the requirements of social forestry received little attention. The National Commission on Agriculture's compelling plea for change in the traditional approach and to generate resources for local people outside reserved and protected forests through well-organised social forestry organisation and community participation considerably influenced the afforestation programmes.

TABLE - 43

PROGRESS OF AFFORESTATION IN FIVE-YEAR PLANS (ANON., 1989)

Period	Afforestation in 000 ha.	Expenditure in millions Rs.
First Plan (1951-56)	52	12.80
Second Plan (1956-61)	311	66.80
Third Plan (1961-66)	583	211.30
Annual Plans (1966-69)	453	230.20
Fourth Plan (1969-74)	714	443.40
Fifth Plane (1974-79)	1221	1072.80
Annual Plan (1979-80)	222	371.00
Total Plan (1951-80)	3556	2410.10
Sixth Plan (1980-85)	4650	9260.10

In the fifth five year plan (1974 - 79), social forestry components were allocated about 50 per cent in the total forestry planting programme. There was a substantial step-up in outlays and targets during the sixth five-year plan (1980 - 85) and the total afforestation targets for the sixth plan far exceeded the total planting targets of the first to the fifth plan period that social forestry received considerable emphasis and social forestry components comprised almost 78 per cent of the total forestry planting

targets. Block plantations on common land, strip plantation on the sides of roads, canals and railways farm forestry and agroforestry on private marginal lands (Plate 22A, 22B) were carried out. Rehabilitation of degraded forest area and planting of fuel and fodder trees were given priority. Funds continued to be made available through the state forest departments and were further supplemented with externally aided social forestry projects in 14 states (NWDB, 1989b). Efforts were made to popularise social forestry programmes in rural areas particularly in the poorest section of the community by distribution of seedlings free of cost.

Neginhal (1949) first reported the important role of bamboo in the ecological development of forest growth and the maintenance of the fertility of forest soils. Prasad (1964) presented the techniques of raising large scale bamboo plantation using bamboo rhizomes and seedlings in the afforestation programme.

Shanmughavel (1994, 1995) studied the performance of *Bambusa bambos* seedling transplanted in the aforestation programmes at Kummittapuram (62.2 ha.) and chickally (49.3 ha.), Sathyamangalam forest division, Tamil Nadu. It revealed that the survival per cent ranged from 70 per cent to 80 per cent in both areas. The height growth of seedlings showed 2.20 m to 4.80. In general, the survival per cent and growth is good at Chickally and Kumittapuram. The annual recruitment of culms at Chickally forest area is given below to show the performance of bamboo raised under afforestation programme (Table - 44).

TABLE - 44

Average recruitment of culms at chickally forest are Sathyamangalam Division, Tamil Nadu

Place : Chickally Annual recruitment of culms

	1992	Height	1993	Height	1994	Height	1995	Height
Beat - I	-	1.15	3	1.65	7	1.95	5	2.20
Beat - II	2	1.85	5	2.40	10	3.10	8	4.80
Beat - III	-	1.40	2	1.90	5	2.25	3	3.01

(Source : Shanmughavel, 1994)

10.8. RECLAMATION OF WASTELANDS

Wastelands may be defined as lands where the production of biomass is less than its optimum productivity. In other words, any land which is not being used to its optimum productivity is wasteland. (NWDB, 1089). These lands results from inherent (or) imposed disabilities. Such lands are ecologically the most unstable and suffer due to various problems such as, soil erosion, ravine, gully, landslide, acidity, alkalinity, water logging, aridity, rockiness etc. Government of India has launched a programme for development of wastelands, in order to revegetate these lands and improve their productivity. Selection of proper tree species for afforestation and revegetation of these lands is the key to success in these programmes. Bamboo being a versatile orborescent grass has largely been planted on these lands. This species being tolerant of

waterlogging, salinity, alkalinity, soil erosion etc. is a natural choice afforestation of several categories of wastelands. Some examples of successful raising of bamboo plantations are follows.

Chauhan et al (1992) conducted a study in district of Kangra of Himachal Pradesh on socio -economic aspect and extent of wastelands. The total area under wasteland is found around 20 ha. per village. Besides the shortage of fuelwood, fodder and timber, the environmental degradation in terms of floods in monsoon and repeated droughts in summer was also noticed there. Rehabilitation - with bamboo plantation is suggested to bring these lands back to health in terms of producing - fodder, fuel-wood and timber besides restoring environmental protection, so that a new profit of Rs. 37,776 per ha. with benefit-cost ratio of Rs. 13.75 can be attained.

Chaturvedi and Bhatia (1993) of Tata Energy Research Institute (TERI) started working in the area of reclamation of saline and alkaline lands in 1986-87. An abandoned agriculture land consisting of three prominent features - Stratum - I, comprising of highly eroded - ravenous land,, Stratum - 3, comprising of waterlogged areas with heavy salinity and alkalinity. The soil is overall sandy and alkaline in nature. The results of the plantation has not only successfully checked soil erosion and soil alkalinity but has also started yielding monetary returns.

Patil (1994) carried out field studies at Dharwad on agricultural lands where the soil and climatic conditions are not favourable for economic cultivation of agricultural crops, have proved that the bamboo *Dendrocalamus strictus* can be successfully cultivated on marginal lands in regions receiving an average rainfall of 750 mm and above.

Shanmughavel and Francis (1995) suggested that the marginal lands and areas that are not used for agricultural crops - canal banks, moist uplands, river bank and farm road sides - can be brought under bamboo plantation. They observed that an average culm emergence of two per clump, one year after planting. The average culm recruitment increased in the subsequent years and numbered at 4 - 13 per clump. The culms that emerged in the first year were short and thin at breast height. Culms produced in the subsequent years were taller and bigger. It was observed that an income of upto Rs. 1000/- could be got in three years from just one clump of bamboo (Plate - 23).

CHAPTER - 11

NEED FOR RAISING BAMBOO PLANTATION

Bamboo is considered to be a unique raw material from the point of its quick growth, easy availability, straightness, smoothers etc. It is used for various purpose such as construction of rural houses, ladders, mats, baskets, pipes and handicrafts etc. But the largest demand is for the manufacture of paper. During the last few decades, it has become a major source of raw material for the Indian Pulp and Paper Industry. The Industry is presently facing problems of non-availability of suitable fibrous raw materials in adequate quantity to meet its requirements. The supply of bamboo, so far the main raw material for the Industry, has been dwindling in the recent years. Still bamboo accounts for 80 percent of the fibrous raw material requirement of the Industry. The report on the National Commission of Agriculture brought out some figures about the current demand and output of the projected bamboo requirements for 1980 (4.274 million (CuM) and 2000 (7.005 million (CuM) and recommended the measures required to bridge the increasing gap between demand and supply (Adkoli, 1992). One such recommendation is, the sustained availability of bamboo can be ensured, only by raising elaborate bamboo plantations, and also to use the existing bamboo resources judiciously and efficiently.

11.1. PRESENT STATE OF PULP AND PAPER INDUSTRIES

Pulp, paper and fibre industries are dependent on raw materials like bamboo, softwoods and hardwoods. Agricultural residues like bagasse, paddy straw, mesta,

kenaf and grasses account for 30 percent of the raw material consumption of pulp, paper and Board industries. The per capita consumption of paper in India is only 2 kg/ Yr-1 as against 200 kg/yr-1 in some advanced countries. The planning commission has estimated to annual requirement of paper products by the year 2000 to be 4,250 million mt yr-1 as against the present installed capacity of 2.754 million mt.

According to statistics collected by the development council for pulp and paper, the installed capacity in India as on 01.01.1992 was 0.3 million mt of newsprint pulp, 0.196 million mt of rayon grade pulp and 0.040 million mt of paper grade pulp. There are 315 mills for the manufacture of paper and paperboards, with a total installed capacity of 67, 62, 379 mt yr-1 (Table - 45)

Seventy five mills are closed. This accounts for a loss of 6.260 million mt in the installed capacity (Table - 46). The effective installed capacity is 1.720 million mt. Production figures for different kinds of paper and paper boards for the year upto 1990 given is Table - 47.

11.1.1. Raw material

Thirty per cent of the raw material used by the paper mills consists of agricultural residues. By technological advances and modernization, it is estimated that the production of paper in the country can increase the use of non-forest raw material to 40 per cent. However, the dependence on forest raw material for major portion of paper manufacture cannot be ruled out. The rayon grade pulp industry in mainly dependent on debarked *Eucalyptus, Casuarina*, bamboo and a small percentage of mixed hardwoods for their manufacture.

The bulk of the bamboo supply to the paper mills was through natural bamboo available in the moist deciduous forests of India. With the exception of Kerala, where reed bamboo available from evergreen forests which is being used by some pulp mills. Most of the bamboo supply comes from two main species viz. *Dendrocalamus strictus* and *Bambusa bambos*. In Northeastern states, bamboo is available in secondary succession after *jhum* cultivation. Bamboo is also grown in homesteads and farms and sold to mills.

11.1.2. Raw material status

Systematic efforts at projecting the wood requirement of the country for industrial and non-industrial uses was first taken up by the National Commission on Agriculture in 1972-1974. The report on the National Commission on Agriculture broughtout some figures about the current demand and output of wood, projected requirements for 1980 and 2000 and recommended the measures required to bridge the increasing gap between demand and suppliers (Table - 48). The Development Council for Pulp and Paper in the Ministry of Industry appointed a raw material committee for pulp and paper. This committee reported on shortages in the year 2000 (Table - 49). The shortages projected by this committee for the year 2000 were 0.300 million t. of bamboo, and 3.55 million t of wood. In addition, the committee projected the shortfall in the raw material for newsprint production to be 0.161 million mt. of bamboo and 0.925 million t of wood. The bamboo shortfall can be compensated only by raising elaborate bamboo plantations.

11.2. GUIDELINES FOR RAISING BAMBOO PLANTATION

Seeds from bamboo are limited and also possessing short period of viability. So the seedlings obtained from tissue culture techniques preferably employed for raising plantation widely.

11.2.1. Preparation of nursery and planting

A nursing area of 10 m x 5 m should be prepared in a field and filled with a mixture of soil and sand in the ratio 3:1. Seedlings when they were about 7 cm in height the seedlings should be removed from polythene bags, and transplanted with about 25 to 30 per square meter in a raised nursery bed, irrigated 2 to 3 times a day taking care to avoid excess saturation. The nursery beds should be provided with a coconut thatch to protect the seedlings from direct sunlight.

11.2.2. Transplantation

The seedlings in the nurseries will be carefully uprooted and transplanted to the field after about 10 months. The seedlings should be planted at 6 m x 6 m spacing with 250 seedlings per hectare. The transplanted seedlings should be irrigated for two hours on a regular basis in both the morning and the evening. Weeds should be removed from the plantation areas as and when required. After one year, the plantation will be irrigated as 15 days intervals. Care is taken to avoid water-logging and the crop should be protected against rodents, grazing and browsing animals.

11.2.3. Production of culms

All transplanted seedlings will begin to produce rhizomes, which inturn produce a number of lateral culms to form clumps. The productivity of bamboo will be assessed by recording the number of new culms produced annually. At a given site the production of new culms will mostly dependent on the culms of the previous years, the degree of congestion and the culmp age.

11.3. RESEARCH WORK ON SELECTING BAMBOO SPECIES FOR PAPER-MAKING

The research work on pulp and paper making with different kinds of bamboo are to be carried out through R & D in the paper industries. During the past five years, research work on pulp and paper making with different bamboo species has been going on. Based on the data derived from these experiments, it was concluded that many species of bamboo such as *Bambusa bambos, B. Vulgaris, B. tulda, Dendrocalamus .strictus, D. hamiltonii* are good for paper making. Produce from these species meets more than 80 percent of the total requirement of raw material for pulp and paper industry in India. Paper made from these were better than those produced from other species of bamboo in strength and physical properties (Shanmughavel, 1995).

The present plantation techniques is based on experience rather than on scientific basis. Species which have attained a crop status in agriculture have long decades of directed endeavour behind them. Bamboos have not attained the same status due to lack of sustained investigations. A few problems of fundamental and applied nature are listed below which need to be tackled immediately.

1. It is necessary to evolve appropriate technology for raising plantations of selected bamboo species particularly in

   a) Degraded ares b) Logged over forest,
   c) Marginal farmland in agroforestry initiatives.

2. Research should be directed to address the role of bamboo in community agro-forestry settings to produce models of the most efficient methods of growing it in waste areas, elevated ground, along field bunds and on river and cannel banks.

3. For raising large scale plantation seedlings from seeds come handly than rhizome propagules. Hence propagation through various vegetative techniques including use of growth regulators should be initiated.

4. Experiments were to be carried out in the bamboo plantations to determine the optimum level of fertilizer needed for increasing production.

11.4. COMPARISON OF PULP AND PAPER MAKING CHARACTERISTICS OF PLANTATION BAMBOO WITH SOME TREE SPECIES

The supply of traditional bamboo species has been dwindling in the recent years. With the gradual shortage of such raw materials the pulp industries are forced to look for alternative stock. Therefore Shanmughavel and Francis (1995) conducted comparative studies on pulp and paper characteristics of plantation bamboo, (*Bambusa bambos) Eucalyptus tereticornis, Acacia decurrens, Acacia arabica and Erythrina suberosa* with a aim to find the

alternate species for bamboo (*Bambusa bambos)*, and *Eucalyptus tereticornis*, 20 percent for *Acacia decurrens* and *Erythrina suberosa* and 22 percent for *Acacia arabica.* The pulp yield in all the species ranges from 43.65 percent to 54.32 percent (Table - 50) which is comparable with 42 - 48 percent of the sulphate process - (Chao and Pan 1972) and 45 - 53% of kraft pulping (Kasim et al 1992). Good tear, burst, tensile and folding endurance values are the requisites of a good quality paper (Razzaque et al. 1981).

In plantation bamboo, the burst factor, tear factor and breaking length was found to be higher in comparison with other tree species. The pulp properties of other tree species were found in the order of *Eucalyptus tereticornis, Acacia arabica, Acacia decurrens and Erthrina suberosa.* However, the strength of paper produced from *Acacia decurrens, Acacia arabica* was relatively lower in folding endurance. This reflects the stiffness of fibres (Caesey, 1980) which is due to thicker cell wall. The lower strength properties of other tree species could be related to the full lignification which occurs during the growth (Kasim et al. 1992). Further more, with the increment of tree age, the cell wall lignified, cellulose structure becomes less exposed and thus hindred the fibre bounding. This circumstances lead to comparatively, lower strength properties of other tree species.

The results of the study indicated that pulp from plantation bamboo has better properties than other tree species. However, comparing the burst, and tear strength of the paper produced from *Eucalyptus tereticornis*, and *Acacia arabica* seems to have potential as a moderate material for pulping, among the hardwoods. Hence next to plantation bamboo (*Bambusa bambos*) these hardwood species can be used as alternative to bamboo.

11.5. ESTABLISHMENT OF A BAMBOO PLANTATION BY PAPER INDUSTRY

The Development Council for Pulp and Paper in the Ministry of Industry, worked out scales of investment needed for pulpwood planting, their economics, suggestions for the management etc. The Ministry of Industry recommended that, the paper industries should be produce 50 percent of their wood requirements by 1990 and 10 percent of their bamboo needs by the year 2000. This could be achieved by the afforestation of a portion of the 82.2 million ha. of wastelands available in India (or) by raising bamboo plantations in the vicinity of industries. The estimated area needed to be afforested in 10 years either by the mills themselves (or) by the joint sector to make up the projected wood short fall was projected to be 0.71 million ha. This was based on an anticipated yield of 50 t ha-1 with a 10 year period of rotation. The deficit of 0.5 t of bamboo could be made up by cultural operations in natural bamboo forests. This effort was suggested to be supplemented by encouraging the taking up of pulp wood in agroforestry on marginal farm lands and extension forestry schemes. The Ministry also recommended strategies for the flow of credit, changes in exiting land laws and provision of incentives to encourage investments by mills on such long gestation crops.

Planting bamboo is more productive in terms of yield (biomass and pulp) than planting other hardwood species suitable for pulping. (Table - 51 and 52).

TABLE - 51

	Bamboo species	Age (yrs)	Biomass t/ha	Reference
1.	Bambus vulgaris	3	7	
2.	Gigantochloa aspera	4	10	Chinte 1965
3.	G. scortechnii (natural stand)	3	71.9	
4.	G. scortechnii	3	36.3	Othman 1993
5.	Bambusa bambos	4	47.4	Shanmughaval 1995

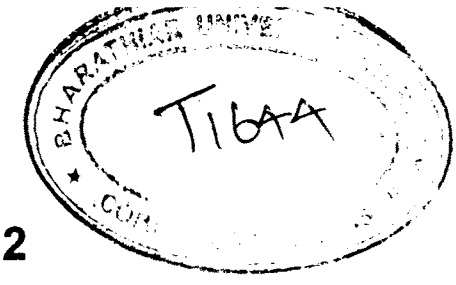
TABLE - 52

COMPARISON OF PULP YIELD (%) OF PLANTATION BAMBOO WITH HANDWOOD SPECIES

	Name of species	Pulp yield (%)
1.	Plantation bamboo (*Bambusa bambos*)	45.0
2.	*Eucalyptus tereticornis*	38.5
3.	*Acacia decurrens*	39.3
4.	*Acacia arabica*	37.0
5.	*Erythronia suberosa*	39.3

Source : Shanmughavel and Francis (1995)

In conclusion, in the new bamboo plantations, the species of bamboo selected must be suitable for paper making, should be fast growing and should give a maximum yield. Research work on raw material storage and processing must be carriedout. Research projects must be well designed and funds assured. Wide publicity must be given about the social significance, economic utility and benefits of raising plantations. The government must also provide low interest loans to the paper industry for raising man made bamboo forests. If full use is made of the bamboo resources and progressive techniques are employed, the paper industry will have a bright future.



CHAPTER - 12

PROBLEMS AND PROSPECTS OF BAMBOO PLANTATION

The present cultivation technique is based on experience rather than on scientific basis. Species which have attained a crop status in agriculture have long decades of directed endeavour behind them. Bamboos have not attained the same status due to lack of sustained investigations. A few problems of fundamental and applied nature and biomass cultivation prospects are listed below.

12.1. CULTIVATION TECHNIQUES

Generally bamboos are cultivated by planting off-sets (or) rhizomes, as seeds are not readily available except in seed years, which again are few and far and far between. Seedlings obtained from tissue culture techniques can also be used. Planting pits are prepared about two months ahead of the planting time and the pit as well as the dug-up soil allowed to weather. Seeds (or) seedling were planted in the field at a spacing of 6 m x 6 m. In one hectare 250 seedlings can be planted. If it is, off-set planting, the collection of off-sets should be done very carefully. They should be properly dug up so that the buds are not damaged in anyway. These are than to be transported as quick as possible to the planting site, ensuring protection against exposure and kept puddled under shade before planting. The time of planting is a most decisive factor in the ultimate success of the plantation. Planting work must be undertaken immediately after the first showers of the monsoon. In plantations, profuse watering is done., but over watering is avoided. All causalities must be

replaced in due course. The plantation will be ready for exploitation within three to five years.

12.1.1. Projection of culms

All the germinated seedlings produces rhizomes, which develop, new rhizomes that produce lateral culms, which are the chief causatives for the total biomass yield. The number of culms developed from the rhizome totally constituted to a clump. During the first year 3 to 4 culms generally increased year after year. The culms produced during first year is shorter in length and smaller in diameter, but culms from subsequent years will be longer in length and bigger in diameter.

12.2. PROBLEMS OF CULTIVATION

There are many irremediable problem, if large scale plantation is planned. The problems relate to seed collection, vegetative propagation, soil moisture conservation, plant protection, weeds, grazing and fire and clump congestion.

12.2.1. Seed collection

Seeds of bamboo resemble grains of paddy (or) wheat and are light weight. Seeds for direct and nursery sowings should be obtained direct from the forest. Possibilities of raising bamboo plantations from seeds is unreliable due to the long and unpredictable flowering habit of the bamboo. (from 25 to 60 years) (Uchimura, 1980). Besides, the seeds have no dormancy period and are viable only for short period. (Anonymous 1948). It is suggested that, a practical and cheap method of prolonging the viability of seeds has to be developed. Some basic studies on seed biology needs to be undertaken.

12.2.2. Vegetative propagation

Various methods of vegetative propagation like off-set planting, layering, rooting of culm and branch cuttings are used for propagation of bamboos. The success and limitations of such propagation methods have been reviewed by Banik (1980) and Hasan (1990). All the four method mentioned above have their merits and demerits. The use of off-set planting and branch cuttings has proved quite successful. But for large scale plantations, however the off-set planting is not the best material as they are bulky and difficult to transport. Seedlings obtained from tissue culture techniques can also be used for raising bamboo plantations. It is clearly understood that, those who wish cultivate bamboo should have, face the difficulty in getting the seedlings.

Hence, seedlings should be provided free of cost by the forest department including technical know how. There should be a motivator for each (or) a group of villages trained in bamboo culture. The farmer should be paid a nominal amount per year 3 to 4 years towards maintenance and protection.

12.2.3. Soil moisture conservation

Soil moisture is a very critical factor. The annual recruitment of culms mostly depended on the soil moisture. It is important to maintain humidity in the soil. So any measure which improves soil moisture is worthwhile. Ploughing the intervening spaces between rows of clumps in one direction and not in a criscross manner for fear of cutting roots on all sides which have a very desired effect. Mounding (or) heaping earth around the bamboo culms should be carriedout each year before the rainy season. (Shanmughavel and Francis, 1995).

12.2.4. Plant protection

The formation of bamboo plantations is not without risks. Young plants, most of which develop the rhizomes in the seedling stage, suffer from depredations by rats, hares, porcupines, squirrels, pigs, deer and cattle including goats. But the chief damage is caused by man, monkeys and elephants. Effective fencing is most essential in the early stages. In the nursery wire-netting should be used to protect the seedling beds from hares which can do a very great harm to them. Insect attack on the new growing culms, (or) on cut bamboos, is a normal factor in bamboo management. In the life of a growing culm, the stage of greatest susceptibility of fungal attack is the "Komali" stage. The green Komali turns brown and comes off easily when pulled, leaving the area of transformation soft and brown,. smelling strongly like molasses. The pathogenic fungi kill a large percentage of komalis and this is commonly experienced in heavy soils of impeded drainage. The measures like drenching the clumpts with blue copper in advance. This may have to be repeated as long as komalis continue to appear. Plan protection measures will go a long way in stepping up the yield.

12.2.5. Weeds

Weeds are the another important problem during the initial stages of plantation. For this weeding was done as and when required. If there is weed competition, the bamboo regeneration suffers more (or) less heavily and shade also thins it out. (Kumar, 1992).

12.2.6. Grazing and fire

Grazing and fire are most detrimental to seedling regeneration. Therefore the plantation area needs protection

from grazing and fire when protection against grazing and fire is not provided the regeneration in form of seedlings are grazed / browsed and killed (Kumar, 1992).

12.2.7. Clump congestion

Congestion in bamboo is one of the most serious problems of management of clumps. Damage by human agency is probably one of the main causes of congestion in bamboos. Clump congestion may be due to (2) too much of soil compaction (b) want of sufficient soil depth for rhizome and (c) development of too many daughter rhizomes in a season. The first defect can be remedied by closing the area to grazing. The second constraint can be overcome by mounding (or) heaping earth around the bamboo clump, inorder to influence the development of future rhizomes outwards (Shanmughavel and Francis, 1995). Development of too many daughter rhizomes, where soil moisture is highly favourable as on river banks will cause congestion and this can be avoided by removing the excess at the komali stage.

12.3. SOCIO-ECONOMIC CONSTRAINTS

To study the socio-economic status of bamboo workers, for example a case study of traditional bamboo workers in Sathyamangalam Taluk, Tamilnadu, is studied and discussed here.

Bamboo is the most versatile forest product in Sathyamangalam forests. It is used by the traditional bamboo workers in this area from times immemorial for a varieity of purposes. High strength to weight ratio, easy workability and comparative cheapness together with availability in abundance and short period of maturity are the reasons of its popularity (Limaye, 1952). It continues to

hold an important place in the rural economy of the developing countries especially in the Asia and Pacific region (Sharma, 1980, 1985). In Sathyamangalam Taluk, the traditional bamboo workers belong to the economically weakers and socially backward strata of the society. Weaving pedels and baskets using bamboo is a traditional occupation of these people. After collecting the raw material from the nearby forests, they manufacture pedels and baskets in their houses and later sell them in the local markets or households. In this part the problem and some socio-economic conditions of bamboo workers are discussed. The results of the study will indicate the appropriate measures for improving the availability of raw material for bamboo workers in producing bamboo based products.

Data was collected from hundred traditional bamboo workers of Sathyamangalam Taluk. Sathyamangalam, Chikkarasampalayam, Vadavalli, Kembanaickanpalayam and Kallipatty areas were selected for the study. A sample survey was conducted to ascertain the problems and socioeconomic constraints of the bamboo workers and the extent to which the present structure helps them to improve their living conditions. In each place, twenty persons (both men and women) were questioned and the data recorded. The major socio-economic variables examined were caste, literacy and income groups (Muraleedharan and Rugmini, 1988).

In the study area, the *Bambusa bambos* is widely used as a raw material for making baskets and other bamboo-wares. Sathyamangalam is famous for bamboo baskets owing to the expertise of the local people and the availability of the raw material. These bamboo are harvested from the neighbouring natural forests of

Sathyamangalam. Generally harvesting of bamboo is not allowed by the Forest Department. According to bamboo workers, some persons knowingly or unknowingly harvest the bamboo and sell to them. The average cost of a 10 m long culm of B. *bambos* is about Rs. 6. 1st quality basket of 75 cm diameter and 60 cm height (7 numbers) requires about three culms. The time taken for weaving one basket is 1 1/2 hours. One middle aged person can make as many as four baskets a day. The net income one can get is Rs. 20, to Rs. 40 per day. Five second quality baskets can also be made from the remaining bamboo strips. The monthly income of bamboo workers in this taluk varies from Rs. 400 to above Rs. 600/-.

Baskets used for domestic and other purposes and containers can be made by these bamboo workers. Their size majority of them are involved in the processing of bamboo either in its harvesting or in weaving. The highest literacy rate was found in Sathyamangalam, followed by Chikkarasampalayam, Kembanaickenpalayam, Vadavalli and Kallipatty respectively (Table - 53). The distribution of bamboo workers according to monthly income groups are presented in Table - 54. It is understood that social and shape and fineness are dependent on the end use and market demands. The big and coarse varieties are used for packing vegetables, fruits, fish and other agricultural produce, while small and fine quality are used as hand carrying baskets. The bamboo basket makers face serious problems, such as the increasing price of raw material, non-availability of raw materials and competition from substitute materials. Some of them want to give up basket making but have no alternatives. Although income from basket making is rather small but they have no alternative resources of their livelihood.

The traditional bamboo workers in the study area belong to Vellalagounder, Kuravar and Valluvar communities (Table - 55). The average size of the family ranges from 4 - 6 members and a backwardness seems to go along with economic backwardness. The survey has shown that the children of the bamboo workers were less educated (or) illiterate. For them, employment opportunities in alternative spheres were negligible. Many of the sample workers expressed their views in favour of setting up of Bamboo Co-operative Societies in Sathyamangalam Taluk. They indicated that the supply of raw material had been dwindling over the years which adversely affected their self-employment and income. Improvement in living conditions of bamboo workers in Sathyamangalam Taluk can be brought about by providing employment opportunities and increasing supply of raw material at a subsidised rate.

From this study it is imperative that Bamboo Co-operative Society should be set up in Sathyamangalam at the earliest, so as to help improving the social and economical status of the bamboo workers in this area along with providing employment opportunities to the educated unemployed youths of this area. Meanwhile necessary action is required to be taken for supply of raw materials to the bamboo workers through the Large Scale Multipurpose Co-operative Societies (LAMPS) with its headquarters located at Sathyamangalam. The results from the studies can be used as guideline for the improvement of bamboo-resource utilization in Sathyamangalam Talum as well as for improvement of income distribution among the bamboo workers.

12.4. PROSPECTS OF BAMBOO CULTIVATION

Major uses of bamboo such as structural material for building purposes and raw material for the pulp,

paper product industries are based on the culm portion of bamboo; other parts of bamboo plant such at leaves, seeds, rhizomes and even the young bamboo shoots equally very useful to the mankind. A brief account of prospects of bamboo cultivation have been discussed here.

12.4.1. Economic analysis

Depending on the nature of use, bamboo classified into (1) Commercial bamboo (2) Industrial bamboo. The commercial bamboo used for all domestic purpose whereas industrial bamboo used exclusively for pulp and paper industries.

The price of commercial bamboo varies according to its length and girth. Hence it is sold as per its length and girth. Different sizes normally sold in market are as given below.

Girth (cm)	Length (m)	Remarks
9 - 12	3 - 5	Each length class
12 - 15	5 - 7	has all girth classes

In Government depots bamboos are sold in lengths varying from 3.10 to 7.50 m. and girth varying from 9 cm to more than 20 cm. Bamboo so purchased from the Government depots is converted into smaller sizes suiting to the local requirements.

Industrial bamboo are sold by the State Forests departments and Forest Corporations directly to the paper

mills. Thinner ends of the bamboos are converted into pieces of 1 m and 2 m. lengths and supplied to the paper mills.

Various workers were questioned for the economy of bamboo plantations. According to Chatruvedi (1986) the benefit-cost (B/C) ratio 1:7 at 14.5 percent rate of discount. In another study Tewari (1981) has tested the economic parameters on costs and benefits data of one hectare bamboo plantation and found that benefit-cost (B/C) ratio as 1.85 at 14 percent discount rate. Shanmughavel and Francis (1993) reported that, cost-benefit (B/C) ratio as 1.51 at 12 percent discount rate and 1.52 at 14 and 16 percent discount rate.

It is now widely recognized that cultivation of bamboo can provide a cost effective return in a short term (after 3 years).

12.4.2. Employment generation

Bamboo is a multipurpose species and its processing is labour intensive providing opportunities for types of diverse employment and may be converted to value added products.

Bamboo plantations provide, direct employment, self-employment and secondary employment based on forest products. Direct employment is provided in the form of managerial, technical research, planning and executive jobs. It has been estimated that, one hectare of bamboo plantation with 500 clumps will generate 3.9 man days of employment for un-skilled labour and 47.3 man days for supervisory and skilled labour over a period of 30 years. (Tewari, 1992).

It has also been estimated that 17 men days will be required to harvest, extract and transport one ADMT (Air Dry Metric Tonne) of bamboos (Misra and Susaeta, 1973).

Self employment is generated when individuals are employed in production process whose output (or) benefits is wholly (or) partly consumed by them. Removal of bamboo headloads, grazing in bamboo forests, lopping it for fodder (or) thatching purposes, availing or rights and concessions are some of the activities which give self employment to the people.

Cottage industries based in bamboo and paper, pulp, paper board and rayon industries provide secondary employment to the people.

CHAPTER - 13

UTILIZATION

13.1. CONSUMPTION PATTERN OF BAMBOOS IN INDIA

The bamboos which are giant, woody, tree-like grasses, have a long history as an exceptionally versatile and widely-used resource. Especially in Asia, where it is known variously as the "poor man's timber", the cradle to coffin plant" and "green-old" bamboo has and still provides, the materials needed for existence. The strength of bamboo culms, their straightness and lightness, combined with hardness, range in sizes, hollowness, long fibre and easy working qualities, make them suitable for variety of purpose. From the tender shoots used for pickles and curries, (or) lowly sticks used per tooth picks and meat barbeques, through the ribs for ubiquitous fans (or) the slats for sun screens, to the sturdy lathies and the so called bamboo houses, the versatility of bamboo is legendry. The thousand and one uses of bamboo have long been known and established. Some of the traditional uses are :

Agriculture implements, anchors, arrows, back scratchers, basket, beds, blinds, boats, bottles, bows, bridges, brooms, brushes, building, caps cart-yokes, caulking material, chairs, chicks, chopsticks, coffine, combs containers, cooking utensils, cordages dust-fans, fans fences, fish-traps, fishing nets, fishing-rods, flagpoles, floats for timber, flutes, flower-pot, food, food baskets, fuel, furniture, hats, handicrafts, haystack stabilizer, hedges, hookah-pipes, joss-stick, kites, ladders, ladles, lamps, lance staves, lanterns, lining of hats, and sandals, loading,

nessels, masts, match-stics, mats, milk-vessels, musical instruments, nails, net-floats, ornaments, paper, pens, polomatlets, rafts, rayon pulp, roofing, ropes, sails, scaffoldings, scoops, seed-drills, shoes, shuttes, tales, thatchings, tobacco pipes, toys tool-handles, traps, tubs, umbrella-handles, walking-sticks, walls, water vessels and wrappers (Plate 24).

The consumption pattern of bamboo for various uses in India is presented in Table - 56.

The general use of bamboos in India is presented in Table - 57.

In addition, bamboo is popular ornamental. As a living plant it is used for hedges, and in landscape gardening. It is valuable as a wind-break and is particularly useful for preventing soil erosion on account of its interwoven root system. In view of the extraordinary range of uses to which bamboos are put they have assumed world importance.

Bamboo leaves are used for thatching and are also valued as fodder; elephants in particular are found of them. Dried and mature bamboo leaves are used for deodorising fish oils. Bamboo sheaths are made use of in lining of hats and sandals; they are also used in an artistic way for dry flower arrangements.

Bamboo seeds are extensively consumed by the poor during famine and the latter, by accident (or) design of nature, are invariably associated with the gregarious bamboo flowering.

The young and tender shoots of certain bamboos such as *Dendrocalamus giganteus* are made into pickles and vegetables which are considered to be delicacies.

In medicine too, bamboo has enjoyed a considerable reputation. Tabashir (or) banslochan which gets precipitated in the form of amorphous silica in microscopically fine state within the culm-internodes of many bamboos is largely used as a cooling tonic and aphrodisiac. Its presence is generally detected by a rattling sound on shaking the bamboo culms. Tabashir, has also been shown to have in purified form excellent properties as a catalyst for certain chemical reactions.

As a result of modern technological advances, new uses for bamboo and bamboo products have been developed. Carbonised filaments made from bamboo fibre have been used as light giving element in special purpose electric lamps.

Preparation of liquid diesel fuel and isolation of crystalline compound related to the female sex hormone from bamboos have also been reported. In addition to certain enzymes which have been extracted from bamboo shoots, an aqueous extract of these shoots has now been found to be superior to conventional media for the culture of certain pathogenic bacteria. The extract when added to tuberculin (a solution of T.B. germs) increases the intensity of responses to the skin test. (Varmah and Bahadur, 1980).

13.2. OTHER RECENT USES

Research is continuously going on to develop new uses of bamboo. Some of the recent uses developed in the country and elsewhere are briefly described as under:

13.2.1. Bamboo parquet (Block flooring)

The term parquet is applied to the flooring in which strips, 3.81 cm x 6.71 cm are cut and laid out in geometric pattern.

13.2.2. Laminated bamboo

The bamboo culms are cracked, spreadout and flattened into sheets with suitable binding and filling material. Then the sheets are combined, lapped, arranged, glued, treated and pressed to the desired form. They are then cut and trimmed to the desired size and shape and finally given finishing touches according to ones fancy.

13.2.3. Bamboo strip for air craft

The use of bamboo-woven mat glued to wood (or) laminated to other bamboo mat for use in light air craft has been studied. The material has been found to be relatively stronger and its fatigue strength under bending stress in much higher than that of wood. The bond strength of bamboo to bamboo is comparable to the bond between bamboo and wood.

13.2.4. Bamboo - reinforced concrete

Bamboo reinforcement was first used in China in 1919 in concrete piles in railways. Since then, the possibility of bamboo reinforcement is being thoroughly investigated.

13.2.5. Artificially - shaped bamboo

Bamboo can be made to grow into square, rectangular and triangular shapes for low cost housing, handicrafts, decoration items and cottage industries. Japan has successfully grown artificially shaped bamboos. Production is simple like moulding hollow blocks, but needs practice. The artificially shaped bamboos are expected to be stronger than round ones.

13.2.6. Bamboo, new raw material for phytoserol

It is found that fermented succulent shoots of bamboo (B.t & D.gi) are enriched source of phytoserols. The concentration of phytoserols ranges from 1.6 to 2.8 % on dry weight basis. It is reported that fermented bamboo shoots can be used as starting materiel in the production of steriodal drugs (Srivastava, 1980).

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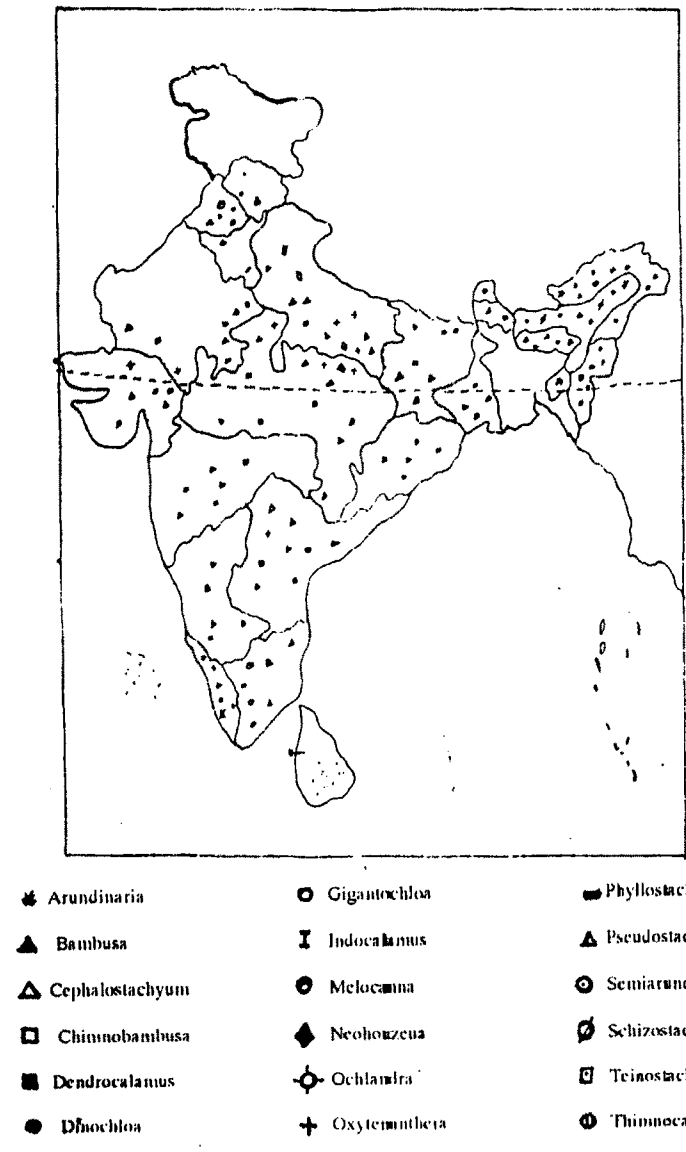

FIGURE - 1

Distribution of Principal Bamboo Genera in India

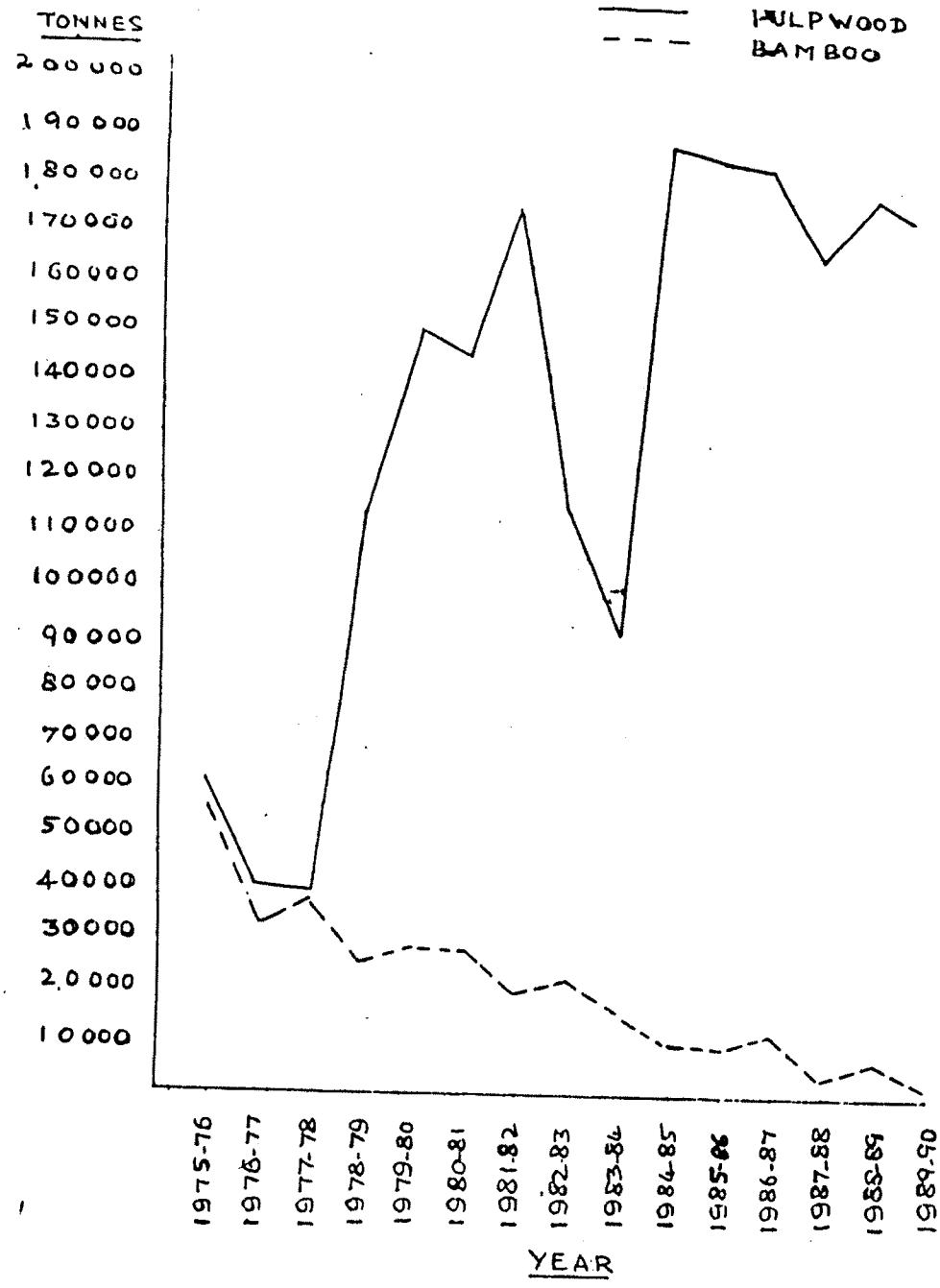

FIGURE - 2

A detailed chart showing supply of bamboos from mid - seventees will show gradual reduction in the supply of bamboos from over 50000 tonnes to around 10000 tonnes now. While the bamboo supply is declining, the supply of Eucalyptus pulp wood has been steadily increasing in Tamil Nadu over the same period.

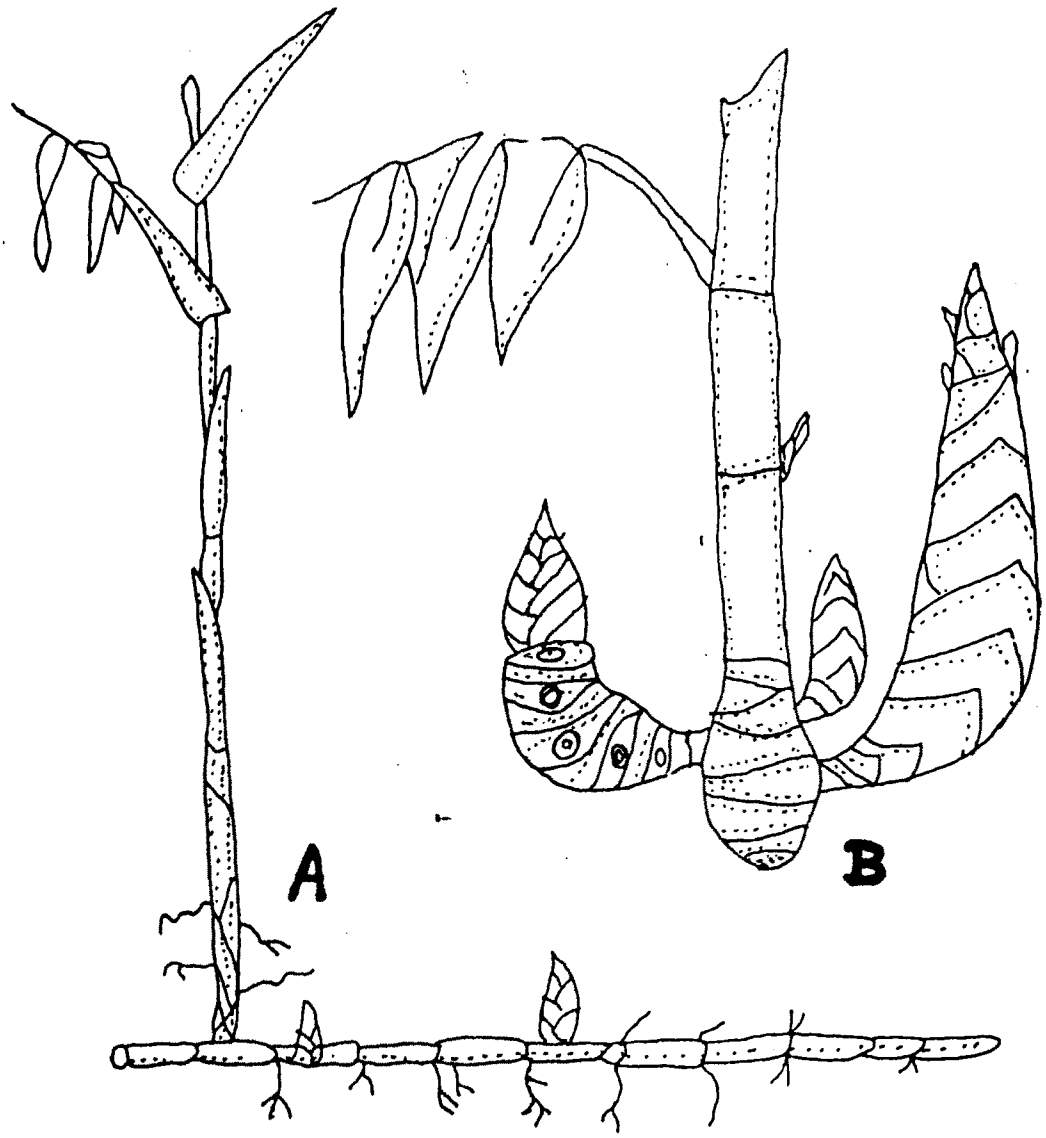

FIGURE - 3

Types of rhizome

A. monopodial (Arundinaria spp)

B. sympodial (Bambusa spp)

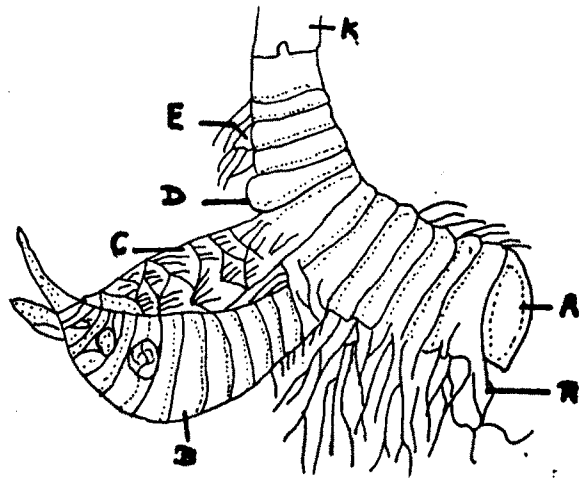

FIGURE - 4

Bambusa bambos

A - Parent rhizome bearing one season old culm (k)

B and C - The new rhizomes developing from parent rhizome (A). The sheaths of the rhizome (B) have been removed so as to expose the internodes and the buds. The basal eight internodes do not show any buds. Development of roots takes place from the dot - like appearances on the internodes of rhizomes.

D and E - Buds on the parent rhizome, which have failed to form new rhizome

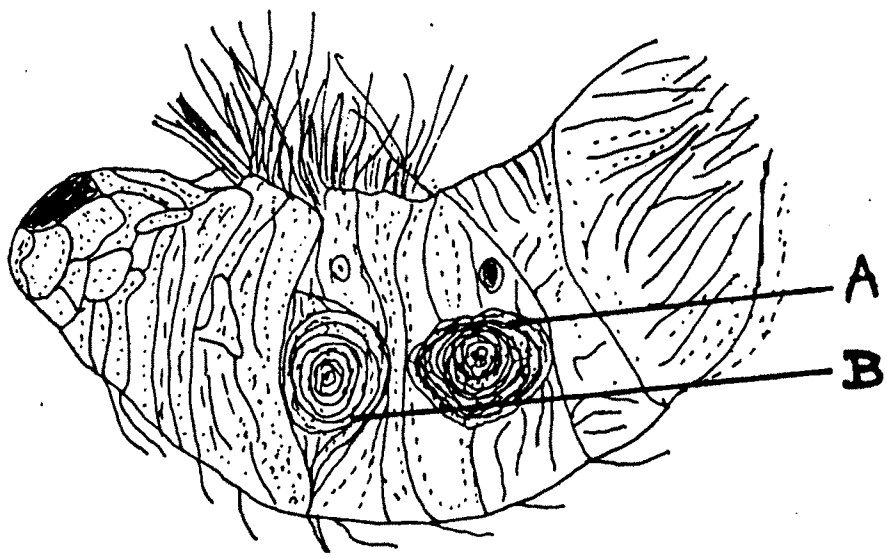

FIGURE - 5

The under ground rhizome showing two buds A and B has been cut across to show internodal details

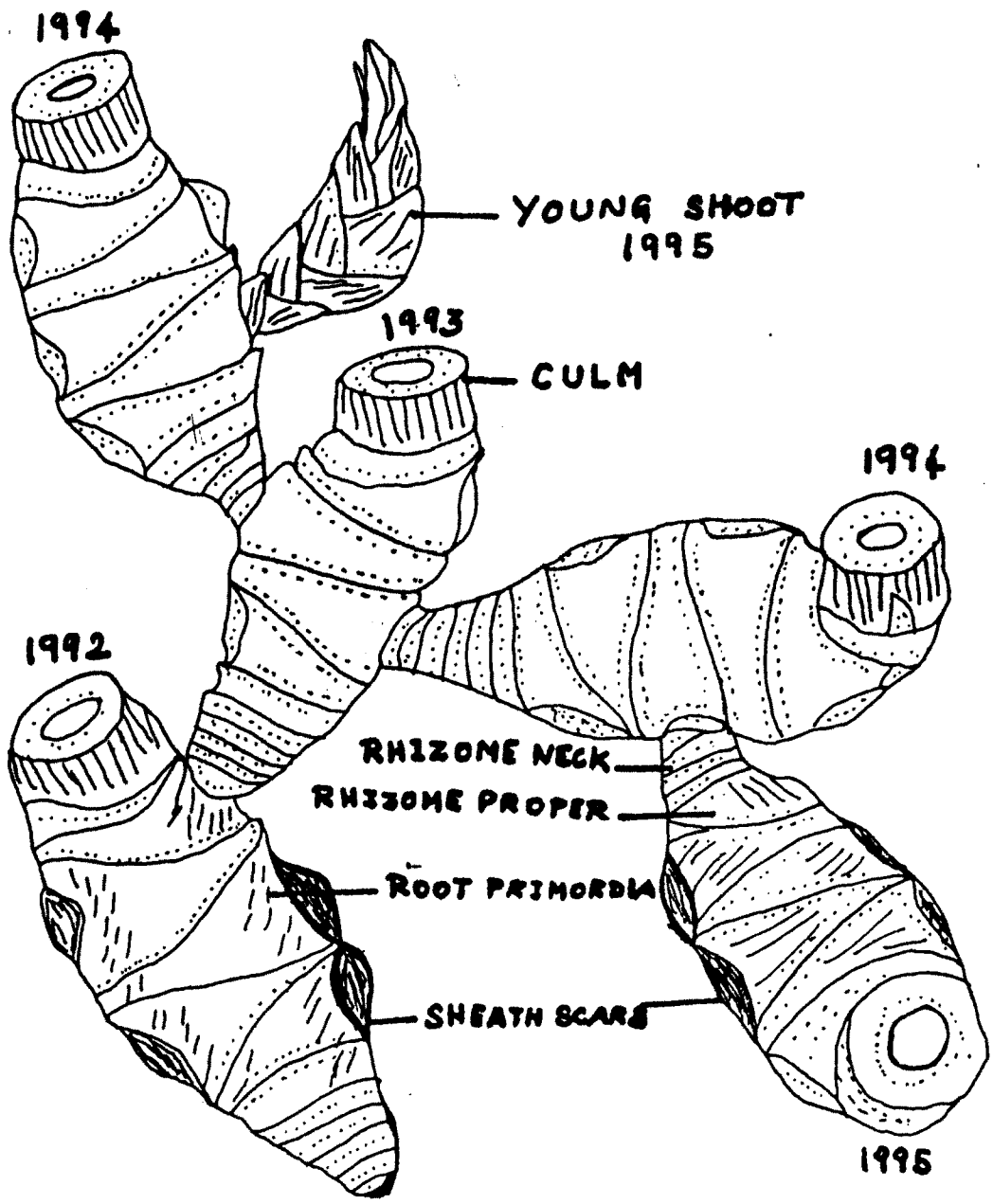

FIGURE - 6

Symbodial rhizome system of bambusa spp., as seen from above, showing individual rhizomes produced in successive years, and the base of the culm invariably terminal to each. The sheaths have been removed (note sheath scars) to reveal lateral buds, root premordia and other details.

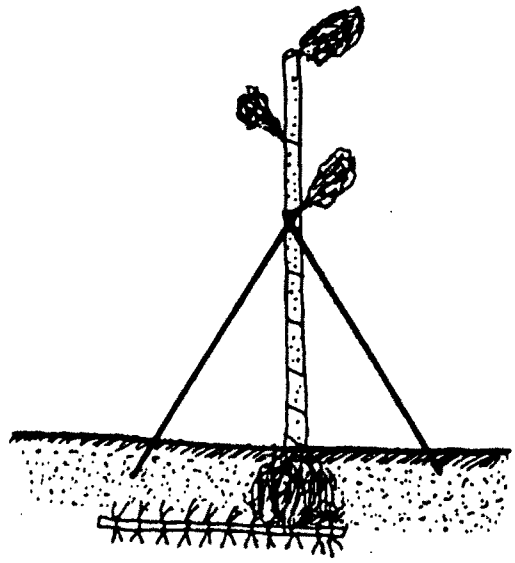

FIGURE - 7

Culm with roots and rhizome

Soil depth : 30 cm
rhizome length : 60 cm

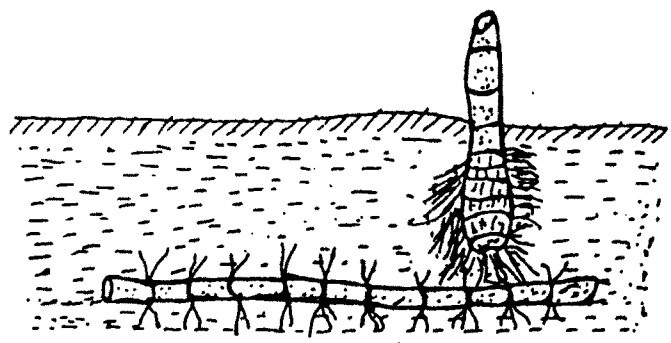

FIGURE - 8

Stock with roots and rhizome

Soil depth : 30 cm
Rhizome length : 60 cm

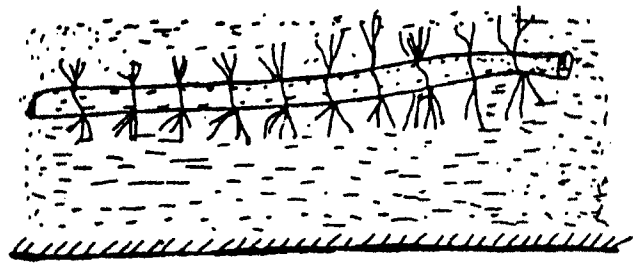

FIGURE - 9

Cutting with rhizome

Soil depth - 20 cm
Rhizome length - 50 cm

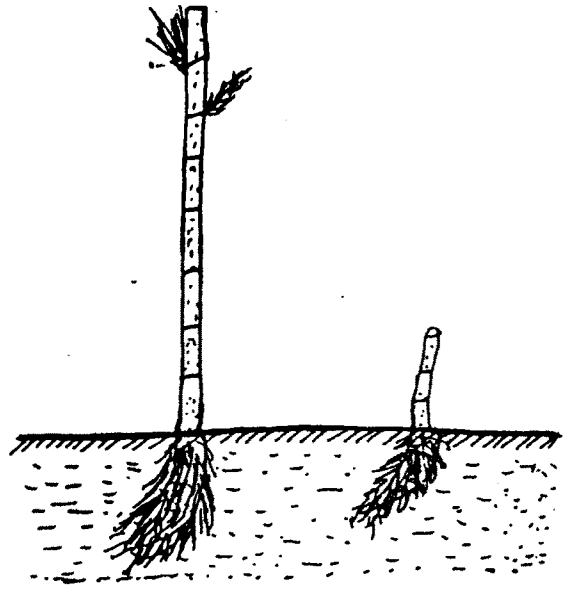

FIGURE - 10

Offset - planting

TABLE - 1 : BAMBOO BEARING AREAS AND POTENTIAL ANNUAL PRODUCTION

Name of State	Bamboo (m. ha) Area	Potential availability (m. tonnes)
Andhra Pradesh	1.98	0.255
Arunachal Pradesh	0.78	0.200
Assam	1.00	1.210
Bihar	0.57	0.200
Gujarat	0.19	0.046
Himachal Pradesh	0.01	0.003
Karnataka	0.60	0.475
Kerala	0.06	0.108
Madhya Pradesh	1.49	0.800
Maharastra	0.85	0.300
Manipur	0.25	0.200
Orissa	1.05	0.489
Punjab	-	-
Tamil Nadu	0.54	0.009
Tripura	0.28	0.215
Uttar Pradesh	0.40	0.041
West Bengal	0.02	0.008
Total	10.03	4.559

(Source T. N. Tewari 1992)

TABLE - 2 : OUT - TURN OF BAMBOO

State/UT's	Bamboo	
	m. tonnes	Nos. in Thousand
Andhra Pradesh	0.307	-
Arunachal Pradesh	-	147.731
Assam (1982-83)	-	1026.000
Bihar	0.080	-
Goa	-	745.680
Gujarat	0.065	-
Haryana	-	745.680
Himachal Pradesh	0.003	-
Karnataka	0.086	-
Kerala	-	1016.343
Madhya Pradesh (1985-86)	0.316	-
Maharastra (1983-84)	0.376	-
Manipur (1983-84)	0.001	-
Orissa	-	162483.262
Punjab	0.0007	-
Rajasthan	-	5133.071
Tamil Nadu (1983-84)	0.011	-
Tripura	0.028	-
Uttar Pradesh	-	9307.000
West Bengal	-	104.206
Anadaman & Nicobar Island	-	1375.610
Total	1.276	181341.768

(Source : India's Forests (1987))

TABLE - 3 : DISTRIBUTION, SOIL AND SITE FEATURES OF SOME BAMBOOS IN INDIA

S. No.	Species	Nature of Soil	Topography status	Moisture	Distribution
1	2	3	4	5	6
1.	Arundinaria falcata	Rich Sandy loam to clayey loam often mixed with stones	Hill slopes high terraces	Moist situation	Western Himalayas, at an elevation of 1300 - 2200 m.
2.	Arundinaria racemosa	- do -	- do -	- do -	Eastern Himalayas; at an elevation of 2200 - 3050 m.
3.	Arundinaria wightiana	Fertile loam	High hills	- do -	Evergreen sholas of Southern India, especially Nilgiris
4.	Bambusa bambos	Flat alluvial rich moist soil; prefers moderately fine clayey soils and tolerates slight water logging; avoids coarse - grained soils and open rides	Flourishes best along the river banks in vallyes and ravines	Moist localities	All over the country except in dry regions and desert areas; mostly in the Indian peninsula; cultivated in sub-Himalayan tract and Indo-Gangetic plains; scarce in Assam and Bengal

S. No.	Species	Nature of Soil	Topography status	Moisture	Distribution
1	2	3	4	5	6
5.	Bambusa polymorpha	Flourishes best on deep, fertile and well-drained loam and riverain alluvium	lower hill slopes and along the valleys; avoids steep precipitions slopes	Moist localities	Bengal, Assam, Kerala, Tamil Nadu; prefers tropical evergreen on semi-evergreen type of climate
6.	Bambusa tulda	Alluvial soils along water courses	Flat land	Prefers moist area	Hill tracts of Assam Bengal, Central India and Decan platean; in moist mixed deciduous forests
7.	Cephalostachyum pergracile	Well drained fresh laom	Low hill country	Between dry and moist sire	Assam, Central India and Decan platean; in dry and moist deciduous forests
8.	Dendrocalamus brandisii	Black loam and loan with lateritic nodules and other good soils	Along the rivers	Moist localities	Kerala, Karnataka and Tamil Nadu; in moist coast climate

S. No.	Species	Nature of Soil	Topography status	Moisture	Distribution
1	2	3	4	5	6
9.	Dendrocalamus hamiltonii	Richy loamy soil	Valley and along streams	Moist places	Central and Eastern Himalayas, up to an elevation of 1000 m in moist deciduous and semi-evergreen forests
10.	Dendrocalamus longispathus	Fertile loam	Mostly along streams	Moist	Bengal, Assam, Kerala and Tamil Nadu; as an associate of moist mixed forests
11.	Dendrocalamus strictus	Poor, coarse grained well-drained dry soils and stony soils on hill sides; avoids poorly drained and moist heary clay soils	Hill slopes, alluvial plains and ravines	Dry areas	Most widely distributed all over the country except northern part of Bengal, Assam and other reny moist areas; occurs in dry open type deciduous fores; common

S. No.	Species	Nature of Soil	Topography status	Moisture	Distribution
1	2	3	4	5	6
					associate of dry sal and dry teak forests. Also occurs on hills and asceds to 1000 m.
12.	Melocanna bambusoides	Fertile loam	Hill slopes and abonded clearings by shifting cultivation	Moist areas	Moist and wet hill tractc of Bengal, Assam and other parts of the country
13.	Oclandra travancorica	Richy loamy soils	Banks of perennial or semi-perennial streams, lower slopes & flat lands	Most areas, prefers running water	Western ghats; as undergrowth in ever green and semi-ever green forests ascending upto 1600 m.
14.	Oxytenanthera monostigma	Shallow rooky soils	Hill tops and ridges	Dry areas	Western and hills of Indian pennisula; as under growth in mixed deciduous forests
15.	Oxytenanthera nigrociliata	Fertile loam	Along streams and lower slips	Moist areas	Orissa, Assam, Central India and Deccan plateau;

Sl. No.	Species	Nature of Soil	Topography status	Moisture	Distribution
1	2	3	4	5	6
					gregarious in semi-deciduous forest of Andaman and Nicobar islands

Source : (Suri and Chauhan - 1984)

TABLE - 4 : STAND CHARACTERISTICS OF BAMBUSA BAMBOS AT KALLIPATTY, TAMIL NADU

	1	2	3	4	5	6	7	8	9
Annual recruitment of culm/ clump	5	9	14	15	16	17	13	11	6
Total culms/ha.	1250	2250	3000	3500	4000	4250	3250	2750	1500
DBH (cm)	2.13±0.22	3.13±0.22	4.2±0.25	4.9±0.25	4.9±0.20	6.2±0.25	5.4±0.12	4.1±0.20	2.8±0.25
Height (m)	1.40±0.37	3.26±0.20	9.6±0.76	21.6±1.49	27.3±0.52	29.0±0.56	20.5±1.00	16.0±1.25	8.5±1.15

TABLE - 5 : ANNUAL FULL GROWN (FG) CLUMP PRODUCTION AND GRADUAL EXPANSION OF CLUMP GIRTH UP TO 10 YEARS OF CLUMP AGE IN FIVE BAMBOO SPECIES OF BANGLADESH

Mean value ± SE

Clump Age (Years)	B. vulgaris		B. balcooa		B. longispiculata		B. tulda		H. baccifera	
	FG culms (Nos.)	Clump girth(cm)	FG culms (Nos.)	Clump girth(cm)	FG culms (Nos.)	Culms girth(cm)	FG Clump (Nos.)	culms girth(cm)	FG Clump (Nos.)	Clump girth(cm)
1	1.6	50.0	1.2	28.5	1.8	30.0	3.0	87.0	2.5	92.2
(1973)	0.2	4.5	0.2	2.0	0.4	5.2	0.5	13.2	0.5	20.5
2	2.8	105.0	2.3	66.3	2.7	66.5	3.8	153.0	5.6	145.9
(1974)	0.3	10.0	0.9	13.5	0.6	13.0	0.4	16.6	1.7	23.2
3	3.2	162.6	1.7	102.0	4.1	140.2	8.2	243.0	12.5	301.0
(1975)	0.7	22.0	0.2	14.0	0.6	16.5	1.3	28.3	2.5	42.0
4	5.3	273.4	2.8	177.0	6.2	222.0	5.7	307.0	16.4	395.4
(1976)	1.2	35.5	0.4	22.6	0.5	24.7	0.9	36.5	4.2	53.3
5	5.2	378.0	3.2	232.0	7.0	286.4	8.8	439.3	23.6	529.3
(1977)	1.7	50.3	0.8	38.0	1.3	20.6	2.3	56.3	7.2	105.6
6	3.6	456.3	2.2	250.0	6.7	372.0	4.5	464.0	25.3	624.3
(1978)	0.8	62.1	0.4	29.4	1.3	28.2	1.0	51.0	4.6	115.2
7	3.2	508.3	2.4	132.5	5.0	430.0	4.9	520.1	26.6	805.4
(1979)	0.6	64.4	0.5	32.5	1.0	35.0	1.2	42.0	8.7	146.1
8	3.2	555.0	1.8	320.5	6.6	507.6	3.7	527.2	25.1	980.6
(1980)	0.6	75.8	0.5	24.0	1.4	66.6	0.3	61.6	6.2	170.5
9	2.6	603.0	2.2	376.0	5.8	648.3	4.8	571.0	31.1	1268.0
(1981)	0.6	58.0	0.5	53.7	1.0	109.3	1.8	57.6	8.0	247.0

TABLE - 6 : VEGETATIVE PROPAGATION BY SINGLE RHIZOME PLANTED IN MAY 1986

Year	No. of new culms	Cumulative total of culms	No. of one-two year old culms extracted for multiplication	Cumulative total of extracted culms	Balance
1970	7	7	-	-	7
1971	13	20	8	8	12
1972	14	34	-	8	26
1973	24	58	20	28	30
1974	18	76	6	34	42
1975	12	88	22	56	32
1976	20	108	-	56	52

TABLE - 7 : CULM POTENTIAL OF BAMBUSA BAMBOS
(Age : 48 months in 1978)

	Number of culms					
Year	CC	MC	GMC	Older culms	Total culms	Available for cutting
1978	8	5	3	20	36	20
1979	12	8	5	3	28	-
1980	18	12	8	3 + 5	46	-
1981	27	18	12	3 + 5 + 8	73	16
1982	40	27	18	12	97	-
1983	60	40	27	12 + 18	157	-
1984	90	60	40	12+18+27	247	57
1985	135	90	60	40	325	-
1986	200	135	90	40 + 60	325	-
1987	300	200	135	40+60+90	825	190

TABLE - 8 : CULM COMPOSITION OF GIGANTOCHLOA SCORTECHNII IN 3-YEAR OLD PLANTATION AND NATURAL STANDS (ha-1)

Location	No. of clump	Average No. of culms/ha.	Average No. of culms/ha.	DBH (cm)	Height (m) 10<	10-15	>15
Natural stand							
% of culm composition	422	8018	19	6.8	4297	3341	380
In Plantation							
Composition by age							
1 year after planting	400	3440	8.6	2.1	3440	-	-
2 year after planting		4320	10.8	3.3	4032	288	-
3 year after planting		2480	6.2	4.6	1488	992	-
Total		10240	25.6		8960	1280	-
% of culm composition					87.5	12.5	

TABLE - 9 : MONTHLY RECRUITMENT OF CULMS/CLUMP

Sample Clump Number

Month	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S
January	3	-	4	-	4	1	1	1	2	-	3	1	4	-	4	1	3	1	3	1	4	1	3	-	4	1	1	-	1	1
February	4	1	4	-	2	-	2	-	3	1	4	1	3	1	3	1	4	1	4	1	4	-	4	1	3	-	2	1	2	1
March	3	1	3	1	3	1	3	-	4	1	3	-	4	2	5	1	2	-	3	1	3	-	5	2	4	1	3	1	3	1
April	2	-	2	-	3	-	2	1	6	1	2	-	3	-	4	-	3	-	4	-	-	-	6	1	5	2	-	-	4	1
May	2	-	2	-	4	1	4	1	3	-	3	-	4	-	3	-	4	1	3	-	-	-	3	-	-	-	-	-	-	-
June	3	-	4	2	4	2	6	2	2	-	4	2	3	2	2	1	5	2	4	1	3	1	4	1	3	1	4	2	3	1
July	5	-	5	2	6	3	8	3	6	3	6	3	4	2	4	3	8	4	6	3	4	1	6	3	7	3	5	1	6	3
August	4	1	5	2	7	3	6	2	8	3	9	4	6	2	6	3	9	3	9	2	5	2	8	3	5	3	6	3	4	2
September	8	4	6	3	8	2	6	4	7	4	6	3	4	1	6	3	3	1	7	3	6	3	8	4	6	4	4	3	6	4
October	6	3	4	1	4	2	3	1	3	-	4	1	6	4	3	2	4	2	4	1	6	4	6	3	3	2	2	1	4	3
November	6	3	3	1	3	1	3	-	4	1	3	1	4	2	3	2	3	1	3	1	4	2	4	1	4	2	3	1	3	2
December	5	1	4	2	3	1	2	2	3	1	3	1	3	2	5	2	2	1	6	2	3	1	3	-	3	1	4	2	4	1
Total culms	16		14		17		17		15		17		18		19		17		18		15		19		20		15		20	

Fifteen clumps were randomly selected from the sixth year plantation for the assessment of culms and their survival were recorded. It revealed the maximum recruitment of the culms took place during September-November, which was the monsoon season. An average of 17 culms were produced from one Culm, during the year 1993.

C - Number of newly sprouted culm
S - Survival

TABLE - 10 : DAILY HEIGHT GROWTH OF *BAMBUSA BAMBOS*

Days	Clump Number 1			2			3			4			5		
	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA
2 (cm)	12	-	4	25	-	3.5	21	-	4.5	44	-	3.5	46	-	4.5
4	20	-	-	28	-	-	34	-	-	61	-	-	65	-	-
6	33	-	-	34	-	-	45	-	-	1.01	-	-	99.5	-	-
8	52	-	-	63	-	-	64	-	-	1.49	-	-	1.4	-	-
10	69	-	-	78	-	-	93	-	-	2.09	-	-	1.5	-	-
12	76	-	-	1.05	-	-	1.17	-	-	2.27	-	-	1.7	-	-
14 (m)	1.02	3.5	4.5	1.14	3.5	4.5	1.51	3.5	5.5	2.5	4.5	5	2.3	4.5	5.5
16	1.52	-	-	1.19	-	-	1.94	-	-	3.1	-	-	2.7	-	-
18	1.9	-	-	2.5	-	-	2.0	-	-	4.0	-	-	3.0	-	-
20	2.0	-	-	2.7	-	-	2.7	-	-	4.2	-	-	3.3	-	-
22	2.2	-	-	3.5	-	-	3.8	-	-	4.4	-	-	3.5	-	-
24	2.5	-	-	4.0	-	-	4.2	-	-	4.5	-	-	3.7	-	-
26	2.6	-	-	4.2	-	-	4.5	-	-	4.7	-	-	3.9	-	-
28	2.8	-	-	4 4	-	-	4.7	-	-	5.2	-	-	4.2	-	-
30	3.4	-	-	5.0	-	-	5.0	-	-	5.7	-	-	4.9	-	-
32	4.0	-	-	5.5	-	-	5.7	-	-	6.6	-	-	5.5	-	-
34	4.5	-	-	6.2	-	-	6.3	-	-	7.0	-	-	5.9	-	-
36	5.5	-	-	6.7	-	-	6.8	-	-	7.2	-	-	6.5	-	-
38	5.7	-	-	7.0	-	-	7.2	-	-	7.2	-	-	7.0	-	-
40	6.0	-	-	7.0	-	-	7.2	-	-	7.2	-	-	7.0	-	-

Days	Clump Number 1			2			3			4			5		
	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA
42	6.0	-	-	7.0	-	-	7.2	-	-	7.2	-	-	7.0	-	-
46	6.5	6.5	7	7.4	5.5	7.5	7.9	6.5	6.9	7.6	5.5	6.5	8.0	5.5	7.5
52	8.0	-	-	8.2	-	-	8.9	-	-	8.6	-	-	8.7	-	-
55	9.5	-	-	9.7	-	-	9.5	-	-	9.6	-	-	9.8	-	-
57	10.7	-	-	11.5	-	-	11.7	-	-	11.5	-	-	11.9	-	-
59	12.0	-	-	12.5	-	-	12.9	-	-	12.7	-	-	13.0	-	-
61	14.5	-	-	14.7	-	-	15.0	-	-	15.5	-	-	15.5	-	-
64	16.0	-	-	16.7	-	-	17.5	-	-	17.0	-	-	17.9	-	-
66	18.5	-	-	18.0	-	-	18.5	-	-	18.0	-	-	19.5	-	-
70	19.0	-	-	20.5	-	-	19.5	-	-	20.5	-	-	21.5	-	-
72	19.9	7.5	9.5	21.5	6.5	7.5	21.5	8	8.5	22.0	6.5	8.5	22.0	6.5	7.5
75	20.5	-	-	22.0	-	-	22.0	-	-	22.5	-	-	22.5	-	-
77	21.0	-	-	22.5	-	-	22.5	-	-	22.5	-	-	23.0	-	-
79	21.4	-	-	22.7	-	-	22.8	-	-	22.7	-	-	23.3	-	-
82	22.0	-	-	23.0	-	-	23.0	-	-	23.4	-	-	24.0	-	-
84	22.3	-	-	23.4	-	-	23.5	-	-	23.5	-	-	24.3	-	-
86	23.0	-	-	24.0	-	-	24.0	-	-	24.0	-	-	24.0	-	-
88	23.5	-	-	24.0	-	-	24.3	-	-	24.0	-	-	24.0	-	-
90	23.5	-	-	24.0	-	-	24.0	-	-	24.7	-	-	24.4	-	-
92	23.5	-	-	24.0	-	-	24.0	-	-	24.3	-	-	24.5	-	-
94	24.0	-	-	24.0	-	-	24.4	-	-	24.7	-	-	24.0	-	-
96	24.5	-	-	24.5	-	-	24.7	-	-	27.8	-	-	24.5	-	-

Days	Clump Number														
	1			2			3			4			5		
	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA
98	27.5	-	-	27.5	-	-	27.5	-	-	28.0	-	-	28.0	-	-
100	28.0	8.5	10	28.0	8	9.5	28.0	8.5	10.5	28.0	8	10	28.0	8.5	10.5
105	28.0	-	-	28.0	-	-	28.0	-	-	28.0	-	-	28.0	-	-
107	28.0	-	-	28.5	-	-	28.0	-	-	28.0	-	-	28.5	-	-
150	28.5	-	-	28.5	-	-	28.5	-	-	28.5	-	-	28.5	-	-
180	29.5	-	-	28.5	-	-	28.0	-	-	28.5	-	-	28.5	-	-
195	29.5	-	-	28.5	-	-	28.5	-	-	28.5	-	-	28.5	-	-
210	28.5	8.5	10	28.5	8	9.5	28.5	8.5	10.5	28.5	8	10	28.5	8.5	10.5

Fifteen clumps were selected at random form the sixth plantation, and identified with marking. New culm sprouting from the selected clumps were taken for growth measurement. On alternate days, the height of each culm was measured and only after reaching 1.37 m height, the diameter at breast height (DBH) was recorded. All observation were made for the basal area girth, DBH, and growth in height, on all culm. The values expressed are the average of 3 clumps.

TABLE - 11 : GROWTH AND BIOMASS OF CULMS

Days	Height	Fresh weight (kg/culm)	Dry weight (kg/culm)	Remarks
2nd day	12 cm	0.500	0.150	Just sprouting
10th day	76 cm	1.633	0.490	
20th day	2.2 m	3.300	0.990	
32nd day	4.5 m	4.625	1.850	Sheaths starts to withering.
52nd day	8.0	13.125	5.250	Branch buds visible.
64th day	16.0	19.625	7.850	At each node, three branch bud clearly visible
75th day	20.5	24.200	12.100	Branches continues to increase in length
96th day	24.5	35.800	17.900	Leaf bud develop on branches.
105th day	28.0	55.600	27.800	Leaf develops
120th day	28.5	72.909	40.100	Leaf develops
135th day	28.5	97.090	53.400	Leaf develops
150th day	28.5	102.650	66.500	
165th day	28.5	134.860	67.400	
180th day	28.5	134.875	67.500	
195th day	28.5	135.160	67.450	
210th day	28.5	135.160	67.450	
219th day	28.5	135.160	67.444	

The growth of the newly developing culm in the 6th year plantation was followed from a 6 year old clump starting from initiation till maturation on the days indicated above. Along with the growth measurement of the culm with its branches and leaves were brought to laboratory, dried and weighed as described under materials and methods. The values expressed are the average of three independent experiments.

TABLE - 12 :PATTERN OF ALLOCATION OF BIOMASS IN GROWING *BAMBUSA BAMBOS* (KG/CULM)

Days	DBH	Height	Basal	Leaf		Branch		Culm		Total above ground biomass	
	(cm)	(m)	area (cm)	fresh weight	dry weight	fresh weight	dry weight	fresh weight	dry weight	fresh weight	dry weight
75th day	7.5	20.5	9.5	-	-	4.800	2.400	19.400	9.700	24.200	12.100
96th day	7.5	24.5	9.5	-	-	5.400	2.700	47.300	15.200	35.800	17.900
105th day	8.5	28.0	10.0	0.700	0.350	7.600	3.800	62.800	23.650	55.600	27.800
120th day	8.5	28.5	10.0	0.836	0.460	9.272	5.100	83.900	34.540	72.908	40.100
135th day	8.5	28.5	10.0	1.290	0.710	11.282	6.500	87.840	46.190	97.000	53.400
150th day	8.5	28.5	10.5	1.610	0.820	13.200	8.580	114.200	57.100	1.2.650	66.500
165th day	8.5	28.5	10.5	1.892	0.910	18.770	9.390	114.300	57.100	134.850	67.400
180th day	8.5	28.5	10.5	1.895	0.920	18.430	9.380	11.840	57.200	134.220	67.500
195th day	8.5	28.5	10.5	1.890	0.950	18.430	9.350	11.840	57.100	135.150	67.450
210th day	8.5	28.5	10.5	1.895	0.900	18.430	9.100	11.840	57.00	135.150	67.000
219th day	8.5	28.5	10.5	1.895	0.946	18.430	9.381	1.840	57.113	135.150	67.444

The culm developed in the 6th year with its components was harvested from the field on specific days mentioned above. The wet weight was determined in the field. They were dried at 103 ± 20 C and the moisture free components were used to determine the dry weight.

TABLE - 13 : ORGANIC MATTER DISTRIBUTION IN 1ST YEAR *BAMBUSA BAMBOS*

S. No.	Sample Culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM) Leaf	Branches	Culm	Total above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
1	1	1	2.2	2.0	1.4	0.100	0.335	0.550	0.975	0.800	1.775
2	2	1	3.5	2.0	1.0	0.125	0.400	0.450	0.975	-	-
3	3	1	3.0	2.0	1.4	0.180	0.350	0.600	1.130	-	-
4	4	1	2.5	2.0	1.8	0.100	0.400	0.750	1.250	-	-
5	5	1	2.5	2.0	1.4	0.150	0.425	0.400	0.975	-	-
6	6	1	3.2	2.0	1.4	0.110	0.300	0.450	0.860	-	-
7	7	1	3.3	2.0	1.4	0.125	0.410	0.600	1.135	-	-
8	8	1	3.5	2.0	1.4	0.190	0.425	0.625	1.240	-	-
9	9	1	3.5	2.0	1.4	0.100	0.350	0.650	1.100	-	-
10	10	1	3.2	2.0	1.4	0.115	0.425	0.500	1.040	0.750	1.790
11	11	1	3.4	2.0	1.4	0.100	0.410	0.700	1.210	-	-
12	12	1	3.0	2.0	1.8	0.150	0.450	0.900	1.500	-	-
13	13	1	3.2	2.0	1.8	0.185	0.400	0.400	0.985	-	-
14	14	1	3.5	2.0	1.8	0.125	0.400	0.800	1.325	-	-
15	15	1	3.5	2.0	1.8	0.150	0.450	0.650	1.250	0.700	1.950

Different components of bamboo such as leaves, branches, culms and rhizome were collected individually from 1-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2° C for dry weight determination.

TABLE - 14 : ORGANIC MATTER DISTRIBUTION IN 2ND YEAR *BAMBUSA BAMBOS*

S. No.	Sample Culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM) Leaf	Branches	Culm	Total above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
16	16	2	3.9	3.0	3.2	0.250	0.750	2.900	3.900	1.100	5.000
17	17	2	3.9	3.0	3.5	0.225	0.700	3.100	4.025	-	-
18	18	2	4.0	3.0	3.0	0.300	0.800	2.700	3.800	-	-
19	19	2	4.2	3.0	3.0	0.325	0.950	2.500	3.775	-	-
20	20	2	4.0	3.0	3.4	0.300	0.750	2.900	3.950	-	-
21	21	2	3.8	3.0	3.5	0.300	0.900	3.000	4.200	-	-
22	22	2	3.9	3.0	3.5	0.315	0.850	2.800	3.965	-	-
23	23	2	4.0	3.0	3.0	0.200	0.900	2.400	3.500	-	-
24	24	2	4.0	3.0	3.1	0.225	0.950	2.600	3.775	-	-
25	25	2	4.5	3.0	3.4	0.300	0.750	3.000	4.050	1.700	5.750
26	26	2	3.9	3.0	3.0	0.325	0.800	2.800	3.925	-	-
27	27	2	4.0	3.5	3.4	0.390	0.950	3.700	5.040	-	-
28	28	2	4.5	3.5	3.3	0.375	0.900	3.900	5.175	-	-
29	29	2	4.0	3.5	3.2	0.325	0.800	3.500	4.725	-	-
30	30	2	4.5	3.5	3.5	0.310	0.900	3.500	4.170	1.940	6.110

Different components of bamboo such as leaves, branches, culms and rhizome were collected individually from 2-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 20 C for dry weight determination.

TABLE - 15 : ORGANIC MATTER DISTRIBUTION IN 3RD YEAR *BAMBUSA BAMBOS*

S. No.	Sample Culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM) Leaf	Branches	Culm	Total above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
31	1	3	4.9	4.0	9.0	0.400	4.100	8.700	13.200	1 500	14.700
32	2	3	4.5	4.0	9.0	0.390	4.500	10.100	14.990	-	-
33	3	3	4.8	4.0	9.0	0.375	5.500	8.500	14.375	-	-
34	4	3	4.5	4.0	9.0	0.350	6.000	8.900	15.250	-	-
35	5	3	5.0	4.0	9.0	0.400	4.800	9.900	15.100	-	-
36	6	3	5.0	4.0	9.0	0.350	6.000	10.000	16.350	-	-
37	7	3	4.9	4.0	9.0	0.300	7.000	9.900	17.200	-	-
38	8	3	4.5	4.0	9.0	0.390	5.100	10.000	15.490	-	-
39	9	3	4.9	4.0	9.0	0.400	6.100	9.750	16.250	-	-
40	10	3	5.0	4.5	10.5	0.500	5.700	10.800	17.000	1.900	18.900
41	11	3	5.2	4.5	10.5	0.375	6.000	10.500	16.875	-	-
42	12	3	5.5	4.5	10.5	0.380	6.000	10.100	16.480	-	-
43	13	3	5.5	4.5	10.5	0.310	5.500	9.100	14.910	-	-
44	14	3	5.5	4.5	10.5	0.310	6.200	10.200	16.710	-	-
45	15	3	5.5	4.5	10.5	0.390	7.100	9.800	17.290	1.600	18.890

Different components of bamboo such as leaves, branches, culms and rhizome were collected individually from 3-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 20 C for dry weight determination.

TABLE - 16 : ORGANIC MATTER DISTRIBUTION IN 4TH YEAR *BAMBUSA BAMBOS*

S. No.	Sample Culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM) Leaf	Branches	Culm	Total above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
46	1	4	5.8	4.5	20	0.400	8.200	20.000	28.600	2.000	30.900
47	2	4	5.9	4.5	20	0.550	7.800	24.950	33.300	-	-
48	3	4	5.8	4.5	20	0.600	7.500	25.600	33.700	-	-
49	4	4	6.0	5.0	23	0.450	7.100	29.000	36.550	-	-
50	5	4	6.0	5.0	20	0.500	7.500	22.000	30.000	-	-
51	6	4	5.9	5.0	22	0.490	8.400	27.000	35.890	-	-
52	7	4	6.0	5.0	23	0.500	7.400	29.000	36.900	-	-
53	8	4	6.3	5.0	23	0.590	7.800	28.800	37.190	1.400	38.590
54	9	4	6.0	5.0	22	0.600	8.500	27.100	36.200	-	-
55	10	4	6.5	5.0	20	0.600	7.500	25.100	34.200	-	-
56	11	4	6.5	5.0	20	0.550	7.500	25.600	33.550	-	-
57	12	4	6.0	5.0	22	0.500	8.100	26.900	28.500	-	-
58	13	4	6.5	5.0	24	0.510	7.500	29.200	37.210	-	-
59	14	4	6.5	5.0	23	0.600	7.100	28.100	35.800	-	-
60	15	4	6.0	5.0	23	0.550	8.500	29.200	38.250	1.700	31.950

Different components of bamboo such as leaves, branches, culms and rhizome were collected individually from 4-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 20 C for dry weight determination.

TABLE - 17 : ORGANIC MATTER DISTRIBUTION IN 5TH YEAR *BAMBUSA BAMBOS*

S. No.	Sample Culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM) Leaf	Branches	Culm	Total above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
61	1	5	7.5	6.0	27	0.750	8.200	39.100	48.050	2.200	50.850
62	2	5	8.0	6.0	26	0.950	7.900	46.000	54.850	-	-
63	3	5	8.0	6.0	27	0.850	8.100	45.100	54.050	-	-
64	4	5	8.0	6.0	27	0.800	8.100	49.700	58.600	-	-
65	5	5	8.0	6.0	27	0.900	8.500	48.100	57.500	-	-
66	6	5	7.5	6.0	27	0.850	8.200	46.900	55.950	-	-
67	7	5	8.0	6.0	27	0.950	8.700	51.100	60.750	-	-
68	8	5	8.0	6.5	28.5	0.900	9.000	42.200.	52.100	-	-
69	9	5	8.5	6.5	27.5	0.900	9.100	42.100	52.000	2.750	54.750
70	10	5	8.5	6.5	27.5	0.950	8.900	42.100	51.850	-	-
71	11	5	8.5	6.5	27.5	0.900	8.900	48.100	57.900	-	-
72	12	5	8.5	6.5	27.5	0.900	8.500	47.000	56.400	-	-
73	13	5	8.5	6.5	27.5	0.950	8.100	51.000	60.050	-	-
74	14	5	8.5	6.5	27.5	0.850	9.000	51.000	60.050	-	-
75	15	5	8.5	6.5	27.5	0.900	8.100	52.700	61.700	2.700	64.400

Different components of bamboo such as leaves, branches, culms and rhizome were collected individually from 5-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 20 C for dry weight determination.

TABLE - 18 : ORGANIC MATTER DISTRIBUTION IN 6TH YEAR *BAMBUSA BAMBOS*

S. No.	Sample Culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM) Leaf	Branches	Culm	Total above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
76	1	6	9.5	8.0	28.0	0.95	10.100	52.100	63.150	2.600	65.150
77	2	6	10.0	8.0	28.5	0.90	8.700	53.800	62.850	-	-
78	3	6	10.0	8.0	28.5	0.90	9.100	62.200	72.100	-	-
79	4	6	10.0	8.0	28.5	0.95	9.200	57.100	67.250	-	-
80	5	6	10.0	8.0	28.5	1.00	9.500	62.100	72.700	-	-
81	6	6	10.0	8.0	28.5	0.90	8.500	56.000	65.400	-	-
82	7	6	10.0	8.0	28.5	0.95	9.700	54.000	64.650	-	-
83	8	6	9.5	8.5	29.5	1.00	9.100	56.200	66.300	-	-
84	9	6	10.5	8.5	29.5	1.00	9.100	54.100	64.200	-	-
85	10	6	10.5	8.5	29.5	1.00	9.800	61.900	72.700	2.400	75.100
86	11	6	10.5	8.5	29.5	0.85	9.500	57.100	67.450	-	-
87	12	6	10.5	8.5	29.5	0.89	9.700	56.100	66.690	-	-
88	13	6	10.5	8.5	29.5	0.90	9.500	53.000	63.400	-	-
89	14	6	10.5	8.5	29.5	0.90	9.800	59.100	69.800	-	-
90	15	6	10.5	8.5	29.5	0.90	9.500	61.900	72.300	2.800	75.100

Different components of bamboo such as leaves, branches, culms and rhizome were collected individually from 6-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 20 C for dry weight determination.

TABLE - 19 : ORGANIC MATTER DISTRIBUTION IN 7TH YEAR BAMBUSA BAMBOS

Sample culm No.	Age (yrs)	Basal area (cm)	Dia-meter (cm)	Height	Leaf	Branches	Culm	TAGB kg/culm	Rhizomes	GTB
1	7	6.0	5.5	20.5	0.600	6.400	35.200	42.200	2.400	44.600
2	7	5.9	5.0	20.4	0.550	6.900	36.100	43.550		
3	7	6.5	5.5	20.0	0.590	6.500	36.500	43.590		
4	7	5.0	5.5	20.5	0.650	7.000	37.100	44.750		
5	7	6.0	5.4	20.5	0.550	6.600	38.100	45.250		
6	7	5.5	5.4	20.4	0.490	7.100	35.100	42.690		
7	7	6.5	5.5	20.5	0.500	5.900	35.700	42.100		
8	7	6.0	5.4	20.5	0.650	7.200	36.000	43.850	2.600	46.450
9	7	6.5	5.5	20.3	0.550	6.500	35.100	42.150		
10	7	6.0	5.5	20.3	0.600	6.100	36.200	42.900		
11	7	6.5	5.4	20.5	0.550	5.900	34.900	41.350		
12	7	6.0	5.5	20.5	0.600	5.900	36.100	42.600		
13	7	6.0	5.4	20.5	0.650	6.100	35.000	41.750		
14	7	6.5	5.5	20.0	0.600	6.800	36.700	44.100		
15	7	6.0	5.5	20.0	0.650	6.500	36.00	43.150	2.600	45.750

TABLE - 20 : ORGANIC MATTER DISTRIBUTION IN 8TH YEAR BAMBUSA BAMBOS

Sample culm No.	Age (yrs)	Basal area (cm)	Dia-meter (cm)	Height	Leaf	Branches	Culm	TAGB kg/culm	Rhizomes	GTB
1	8	5.0	4.0	16.5	0.450	5.100	28.500	34.050	2.000	36.050
2	8	5.0	4.0	16.8	0.400	5.500	23.500	29.400		
3	8	5.5	4.3	17.0	0.500	6.600	23.100	30.200		
4	8	5.0	4.5	16.0	0.450	5.500	26.500	32.450		
5	8	5.3	4.0	16.5	0.500	5.800	20.100	26.400		
6	8	5.0	4.0	16.5	0.490	5.500	25.800	31.790		
7	8	5.0	4.0	16.0	0.500	5.000	26.100	32.600		
8	8	5.4	4.5	16.5	0.590	5.500	27.200	33.290		
9	8	5.0	4.1	16.0	0.550	5.700	26.500	32.750	2.100	34.850
10	8	5.0	4.0	16.5	0.500	5.000	24.700	31.200		
11	8	5.0	4.2	16.4	0.550	5.500	23.500	29.550		
12	8	5.3	4.5	16.0	0.500	5.000	18.800	24.300		
13	8	5.0	4.0	16.5	0.510	6.100	27.200	33.810		
14	8	5.0	4.0	16.5	0.550	5.600	25.800	31.950		
15	8	5.3	4.5	16.0	0.550	6.000	28.100	34.650	1.800	36.450

TABLE - 21 : ORGANIC MATTER DISTRIBUTION IN 9TH YEAR BAMBUSA BAMBOS

Sample culm No.	Age (yrs)	Basal area (cm)	Dia-meter (cm)	Height	Leaf	Branches	Culm	TAGB kg/culm	Rhizomes	GTB
1	9	3.5	2.8	9.5	0.300	4.000	10.100	14.400	1.660	16.000
2	9	3.5	2.8	9.0	0.300	4.150	13.500	17.950		
3	9	3.5	3.0	8.5	0.350	5.000	15.100	20.450		
4	9	4.0	3.0	8.5	0.400	4.000	14.200	18.600		
5	9	4.0	3.0	8.5	0.300	4.100	13.000	17.400		
6	9	3.5	2.8	8.0	0.325	4.300	10.000	14.625		
7	9	3.5	2.8	8.5	0.300	4.700	10.500	15.500		
8	9	4.0	3.0	8.5	0.290	4.100	14.100	18.490		
9	9	4.0	3.0	9.0	0.300	4.00	13.500	17.800	1.300	19.100
10	9	3.5	2.8	9.0	0.350	4.200	15.100	19.650		
11	9	3.5	2.8	8.5	0.300	5.000	15.500	20.800		
12	9	4.0	3.0	8.0	0.300	4.500	16.100	20.900		
13	9	3.5	2.8	8.5	0.310	4.500	15.100	19.910		
14	9	3.5	2.8	8.5	0.350	4.000	15.000	19.350		
15	9	3.5	2.8	8.5	0.300	4.200	14.100	18.600	1.200	19.800

TABLE - 22 : MEAN BIOMASS PRODUCTION, NET PERIODIC INCREMENT AND NET PRIMARY PRODUCTION (T/HA/YR)

Age (years)	1	2	3	4	5	6
Mean annual production	2.29	6.25	17.48	31.95	48.86	49.64
Mean periodic annual production	2.29	10.22	39.95	75.36	106.48	63.55
Litter fall	N.D.	N.D.	N.D.	15.40	17.60	20.30
Net primary production	N.D.	N.D.	N.D.	90.76	124.08	83.85

Mean biomass production, net periodic increment and net primary production were calculated from the productivity data. The data on mean periodic increment and net primary production showed that the rate of biomass accumulation was highest at the age of fifth year, during which a peak of 124 08 t/ha/yr in the net primary production was obtained. (N.D. = not determined).

TABLE - 23 : PRODUCTION OF BIOMASS ON UNIT AREA BASIS (TONNES/HA)

Age (years)	Culm diameter (cm)	Culm diameter (cm)	Basal area (cm)	Number of culms	Number of nodes	Biomass t/ha Leaf	Branches	Culm	Total above ground biomass	Rhizome biomass	Grand total biomass
1	2.3	1.4	3.1	1250	7	0.166	0.493	0.698	1.356	0.938	2.294
2	3.3	3.2	4.0	2250	16	0.668	1.897	6.795	9.360	3.150	12.510
3	4.3	9.6	5.0	3000	37	1.122	17.115	29.250	47.487	4.980	52.467
4	4.8	21.8	6.1	3500	86	1.862	27.160	92.750	121.772	6.055	127.827
5	6.3	27.2	8.3	4000	98	3.544	33.940	187.224	224.708	9.600	234.308
6	8.3	28.5	10.1	4250	103	4.021	39.886	242.730	286.637	11.220	297.857

The culm branches, leaves and rhizome were collected individually and after determining their fresh weight at the field, were oven dried at 103 ± 20 C in the laboratory. Their moisture free dry weight was determined. Their individual weight are expressed at t/ha. The value expressed are average of three independent experiments.

TABLE - 24 : GROWTH STATISTICS OF BAMBOO IN WASTELAND RECLAMATION

Replication Number	Year 1989	1990	1991	1992	Mean	S.D.
Acacia nilotica xDendrocalamus strictus						
I	15	52	58	25	37.5	17.9
II	63	76	57	70	66.5	7.2
III	10	15	24	26	18.8	6.5
IV	9	27	32	35	25.8	10.1
V	5	15	23	26	17.3	8.1
Total	102	185	194	182	65.8	37.1
Casuarina equisetifolia x Dendrocalamus strictus						
I	86	160	100	105	112.8	28.2
II	66	87	75	131	89.8	24.9
III	49	91	110	151	100.3	36.7
IV	14	37	49	84	46.8	25.3
V	11	26	47	51	33.8	16.2
Total	226	401	381	522	382.5	105.2

TABLE - 25 : THE NET PRODUCTIVITY OF BAMBOO IN MIXED PI ANTATION

Plot No.	1992 Culm No.	1992 Green	1992 Air dry	1993 Culm No.	1993 Green	1993 Air dry	1994 Culm No.	1994 Green	1994 Air dry
Acacia nilotica x Dendrocalamus strictus									
I	67	2.31	1.80	58	2.00	1.56	25	0.86	.067
II	139	4.80	3.73	57	1.97	1.53	70	2.63	2.05
III	25	0.86	0.67	24	0.83	0.65	26	0.90	0.70
IV	36	1.24	0.96	32	1.11	0.86	35	1.21	0.94
V	20	1.98	1.54	23	0.79	0.61	26	0.90	0.70
Total	287	1.98	1.54	194	1.34	1.04	182	1.26	0.98
Casuarina equisetifolia x Dendrocalamus strictus									
I	246	8.50	6.61	100	3.45	2.69	105	3.63	2.82
II	153	5.29	4.11	75	2.59	2.02	131	4.53	3.52
III	140	4.84	3.76	110	3.80	2.96	151	5.22	4.06
IV	51	1.76	1.37	49	1.69	1.32	84	2.90	2.90
V	37	1.28	0.99	47	1.62	1.26	51	1.76	1.37
Total	627	4.33	3.37	381	2.63	2.05	522	3.61	2.81

Note : 1. Only culms expected to be harvested in respective years are given in the table

2. All weight are Tonnes per hectare

3. Biomass of trees has not been included

TABLE - 26 : ABOVE GROUND BIOMASS OF GIGANTOCHLOA SCORTECHNII

	Nature Stands	Plantation age* (Year) 1	2	3	Over all
Number of culm (pcs/ha)	8018	2480	4230	3440	10240 (T)
Average DBH (cm)	6.8	2.1	3.3	4.6	3.3 (A)
Average height (m)	13.3	3.8	6.7	9.2	6.6 (A)
Fresh weight of culms (ton/ha)	82.15	3.3	14.1	24.4	14.8 (T)
Fresh weight of branches (ton/ha)	20.00	1.0	3.9	6.5	11.4 (T)
Fresh weight of leaves (ton/ha)	16.90	0.7	3.1	7.4	11.2 (T)
Dry weight of culms (ton/ha)	52.90	1.8	8.1	14.9	24.8 (T)
Dry weight of branches (ton/ha)	9.80	0.6	2.1	3.4	6.1 (T)
Dry weight of leaves (ton/ha)	9.20	0.3	1.5	3.5	5.3 (T)
Total dry (ton/ha)	71.90	2.7	11.7	21.8	36.2 (T)
Dry matter density (kg/m3)	0.54				0.55 (T)

* Year after planting; T - Total; A - Average

TABLE - 27 : PERCENTAGE OF INDIVIDUAL CULM COMPONENTS

Age (years) (cm)	Average diameter (m)	Average height (%)	Leaf biomass (%)	Branch biomass (%)	Culm biomass (%)	Rhizome biomass (%)
1	2.3	1.4	07	21	32	40
2	3.3	3.2	05	15	55	25
3	4.3	9.6	.02	33	56	09
4	4.8	21.8	02	20	73	05
5	6.3	27.2	02	14	80	04
6	8.3	28.5	01	14	85	04

The percentage individual culm components were calculated.

The culm contributes the maximum biomass by branch, rhizome and leaves.

TABLE -28 : BIOCHEMICAL CHARACTERISTICS OF BAMBOO LEAF

Age in years	Total chlorophyll (µ/g)	Chloro-phyll a (µ/g)	Chloro-phyll b (µ/g)	Chloro-phyll a,b ratio	Caroten-oides	Protein (µ/g)	Carbo-hydrate (mg/g)	Starch (m/g)
Wild	602	266	328	0.81	91.35	10.41	12.00	811.95
1	551	248	298	0.83	64.00	7.53	8.78	588.35
2	544	237	302	0.78	58.83	7.23	7.95	537.30
3	500	230	265	0.86	53.55	6.89	7.20	495.65
4	449	212	233	0.90	50.42	6.19	7.04	481.72
5	398	194	200	0.97	49.88	6.07	6.91	475.09
6	366	174	188	0.92	48.80	5.95	6.47	469.82

Chlorophyll, carotenoides, protein, carbohydrate and starch were analysed from fresh leaves as described in materials and methods.

The values expressed are average of three independent experiment.

TABLE - 29 : COST FOR MAINTENANCE AND EXPENDITURE INCURRED ON EXTRACTION OF BAMBOO

Years	Cost of raising the plantation maintenance (Rs.)	Expenditure incurred on extraction of bamboo (Rs.)	Total expenditure	Total revenue obtained
1	11,400	-	11,400	-
2	6,750	-	6,750	-
3	5,145	-	5,145	-
4	6,415	30,000	36,415	56,250
5	6,320	25,125	34,445	60,500
6	8,150	50,000	58,150	114,750
	44,180	108,125	152,305	231,500

Surplus amount Rs. 79,195.

TABLE - 30 : COST - BENEFIT ANALYSIS FOR SIX YEAR OLD BAMBUSA BAMBOS PLANTATION

Year	cost (Rs.)	Benefit (Rs.)	Present value under different discount rate 12% cost (Rs.)	12% Benefit (Rs.)	14% cost (Rs.)	14% Benefit (Rs.)	16% cost (Rs.)	16% Benefit (Rs.)
1	11,400	-	10,032	-	9,804	-	9,596	-
2	6,750	-	5,940	-	5,805	-	5,670	-
3	5,145	-	4,527	-	4,340	-	4,321	-
4	36,415	56,250	32,047	49,500	31,319	48,375	30,591	47,250
5	34,445	60,500	30,311	53,240	29,622	52,030	28,933	50,820
6	58,150	147,500	134,029	203,720	130,899	199,090	127,657	194,460
Total	152,305	234,500	134,029	203,720	130,899	199,090	127,657	194,460

Discount rates : 12% B/C ratio = 1:51, 14% ratio = 1.52 and 16% B/C ratio = 1:52

(Source : Shanmughavel and Francis, 1993)

TABLE - 31 : COMPREHENSIVE TYPE ESTIMATE FOR RAISING IRRIGATED PLANTATION OF DENDROCALAMUS STRICTUS SPACING 4X4 M (625 NOS/HA).

Sl.No.	PARTICULARS OF WORK	Quantity	Rate	Per	Amount
1.	Raising of seedlings in nursery	625 Nos.	3.00	each	1875.00
2.	Clearing the area i.e. removal of weed growth if any, wherever necessary	1.00 ha.	99.00	ha.	99.00
3.	Digging Pits for CPT 1.50 M width on top 1.00 M width at bottom 1.00 M depth i.e., 1.25 cum pet mt. Average length of boundary per ha. will be 280 mt. 280 x 1.25 = 350 cum (wherever CPT is not feasible, barbed wire fencing is to be done)	350 cum	9.80	cum	3330.00
4.	Aligning and marking on the ground with pickaxe for digging pits	625 Nos.	2.835	1000	17.71
5.	Digging pits of size 0.8 x 0.65 x 0.65 M	625 Nos.	2.00	each	1250.00
6.	Purchase of cowdung 3 cart loads per ha.	3 cart loads	75.00	each	225.00
7.	Mixing cow dung at the time of refilling pits, 2 male mazdoor per ha.	2 Nos.	16.70	each	33.40
8.	Refilling of pits	625 Nos.	0.50	each	312.50
9.	Transport of bamboo seedlings	625 Nos.	435.60	1000	
272.87					
10.	Transport to planting site	625 Nos.	120.10	1000	75.06
11.	Planting	625 Nos.	110.00	1000	68.75
12.	Soil Working	625 Nos.	446.00	1000	278.75
13.	First Weeding	1 ha.	131.75	ha.	131.75
14.	Purchase of Manure				
	a) Mussorie Phos 500 gms	625 x 0.5 kg = 312.50 Kg/ha.			312.50
Kgs	0.70 Kg.	218.75			
	b) DAP 50 gm. per clump	625 x 0.5 kg = 31.24 Kg/ha.			31.25 5.00
Kg.	156.25				
15.	Application of Fertiliser	625 Nos.	17.75	1000	11.09
16.	Second Weeding	1 ha.	105.50	ha.	105.50
17.	Watering from November to May	1 ha.	L.S.		1500.00
18.	Miscellaneous		L.S.		531.62
	TOTAL				10493.00

TABLE - 32 : FIBRE LENGTH IN *BAMBUSA BAMBOS*

Age in Years	1	2	3	4	5	6
Bamboo density (gm/cc)	0.588	0.593	0.598	0.610	0.617	0.622
Average fibre length (mm)	2.0	2.0	2.3	2.3	2.5	2.5
Chips density (BD) kg/m3	200.41	202.10	208.10	215.00	220.10	224.76

Fibre length was determined.The results ex pressed are average of three independent experiments.There was no significant variation in the fibre length of 1st year (2 mm) to 6th year (2.5 mm) bamboo.

TABLE - 33 : FIBRE CLASSIFICATION (UNBLEACHED PULP)

	Age in Years					
Fibre classification	1	2	3	4	5	6
+50 mesh fibre (%)	68.10	68.90	69.10	69.80	69.96	69.96
+65 mesh fibre (%)	7.44	8.10	8.42	8.92	8.92	8.92
+100 mesh fibre (%)	3.72	3.74	3.80	3.83	3.83	3.83
-100 mesh fibre (%)	18.88	18.96	19.00	19.09	19.09	19.10

Fibre classification of unbleached pulp was made. The results expressed are average of three independent experiments. All the fibre per cent found to be increased with age.

TABLE - 34 : FIBRE CLASSIFICATION (BLEACHED PULP)

Fibre classification	Age in Years					
	1	2	3	4	5	6
+50 mesh fibre (%)	76.10	78.20	79.12	80.27	80.40	80.70
+65 mesh fibre (%)	9.39	9.42	9.63	9.70	9.89	9.90
+100 mesh fibre (%)	5.10	5.24	5.40	5.42	5.50	5.51
-100 mesh fibre (%)	4.33	4.53	4.62	5.00	5.10	5.10

Fibre classification of bleached pulp was made.The results expressed are average of three independent experiments. All the fibre per cent found to be increased with age.

TABLE - 35 : PROXIMATE CHEMICAL ANALYSIS

Age in years	Ash (%)	Cold water solubles (%)	Hot water solubles (%)	Alcohol benzene solubles (%)	1% NaOH solubles	Pentosans (%)	Lignin (%)	Cellulose (%)	Moisture (%)
1	1.20	4.00	4.47	7.50	20.50	19.10	28.00	60.01	40.0
2	1.50	4.00	4.60	7.50	21.90	19.32	28.50	61.20	40.0
3	1.70	4.20	4.90	7.90	22.50	19.53	29.00	62.50	45.0
4	1.90	4.20	5.10	8.00	23.00	19.62	30.50	63.30	50.0
5	2.10	4.30	5.80	8.00	23.00	20.33	31.50	64.50	50.0
6	2.30	4.50	5.95	8.00	23.50	20.20	32.00	65.60	50.0

The first year of sixth year old culms were harvested for studying their proximate chemical composition. The results are the average of the three independent experiments. Gradual minimal increasing trends of all the proximate chemical components was noticed.

TABLE - 36 : PULPING DATA

Characteristics	Age in Years					
	1	2	3	4	5	6
Total pulp yield (%)	46.36	47.23	48.10	48.30	48.44	48.80
Knots (%)	2.27	2.19	2.24	2.26	2.30	2.30
Kappa number	27.20	27.60	27.60	28.90	28.90	28.90

Total pulp yield, knots and kappa number was calculated. The pulp yield found to be increased from (1st year) to 48% (6th year).

TABLE - 37 :PHYSICAL STRENGTH PROPERTIES OF UNBLEACHED PULP

Characteristics	Age in year					
	1	2	3	4	5	6
Buster factor	47.8	48.0	48.2	48.9	49.0	49.1
Tear factor	80.0	82.0	84.0	85.0	86.0	86.5
Breaking length (m)	6706.0	6780.0	6990.0	7210.0	7222.0	7222.0
Double folds	85.0	95.0	120.0	150.0	160.0	180.0

Physical strength properties of unbleached pulp were made. The results expressed are average three independent experiments. The physical strength properties increased with age.

TABLE - 38 : BLEACHABILITY TEST

Characteristics	Age in Years					
	1	2	3	4	5	6
Initial brightness (%)	30.0	30.0	32.0	33.0	33.0	33.0
Final brightness (%)	75.0	76.0	78.0	80.0	80.0	84.0
Cl2 consumption	8.91	9.10	9.49	10.0	10.49	10.49
Bleaching loss (%)		14.04	13.57	13.57	13.60	13.63

The bleachability test was carried out. The results expressed are average three independent experiments. The chloride consumption for bleaching increased with age. The bleaching loss also increased with age.

TABLE - 39 : PHYSICAL STRENGTH PROPERTIES OF BLEACHED PULP

Characteristics	Age in year					
	1	2	3	4	5	6
Buster factor	37.5	38.0	42.5	42.5	43.5	44.0
Tear factor	63.9	64.9	66.7	68.0	68.9	68.9
Breaking length (m)	4933.0	5011.0	5316.0	5410.0	5415.0	5415.0
Double folds	70.0	85.0	90.0	120.0	130.0	140.0

The physical strength properties of bleached pulp was carried out. The results expressed were average of three independent experiments. The physical strength properties increased with age.

TABLE - 40 : BLACK LIQUOR ANALYSIS

Characteristics	Age in Years					
	1	2	3	4	5	6
Total solids (gpl)	200.00	205.1	206.0	208.0	209.0	209.0
Inorganics (%)	46.90	47.69	48.10	48.10	48.33	48.33
Organics (%)	51.67	51.90	52.8	52.90	52.91	52.91
Acid. insolubles (gpl)	4.20	4.37	4.90	5.10	5.50	5.50
Na2O (gpl)	54.14	54.20	54.64	55.10	55.17	55.19
Swelling volume ratio (ml/gm)	25.0	25.0	26.0	27.0	27.0	27.0
Calorific value (cals/gm)	3795.0	3810.0	3894.0	3910.0	3960.0	3968.0

The block liquor analysis was carried out. The results expressed are average of three independent experiments. The characteristics studied were increased with age.

gpl - gram per litre; gm - gram; Cals- calories.

TABLE - 41 : RESULTS OF THREE ELEMENTS TEST

i) Pleioblastus — Per plot (diameter 1m = 0.7825 m2)

Plot (treatment)	Growth in a year after Planting	No of culms	Culms: Average diameter at base (cm)	Culms: Whole length (average) (cm)	Culms: Fresh weight of leaves (g)	Culms: Total fresh wt. culms branches (g)	Culms: Index No. by total weight	Rhizomes: Total elongation (mn)	Rhizomes: Average diameter (g)	Rhizomes: Total fresh weight	Rhizomes: Index No. by total weight	Rhizomes: No. of branches
Complete plot treatment elements		46	4.6	72	166	526	100	1877	5.9	745	100	40
Non-nitrogen plot		15	4.7	57	34	147	28	677	5.8	325	44	8
Non-phosphorus plot		16	4.7	74	49	215	41	810	5.7	325	44	11
Non-potash plot		21	4.4	78	64	281	53	1005	5.3	405	54	20
Non-fertilizing		17	3.8	63	46	182	35	774	5.0	288	39	8

Remarks : Applied amounts of fertilizers (per 1 plot) 124 g. Ammonium sulphate (N:268) 86 g. Super phosphate of lime (P2O5) (3.8 g) 49 g. Potassium sulphate (K2O; 23.5 g);

Locality : Experimental station of kyto university

TABLE - 42: RESULTS OF THREE ELEMENTS TEST

ii) Phyllostachys reticulata Grove Area of 1 plot = 100 m2 (10 x 10 m)

Kinds of plot by applied)	Number 1st year	Index No.	2nd Year	Index No.	Fresh weight (kg) Ist year (kg)	Index No.	2nd Year (kg)	Diameter at eye height (average) Index No.	1 stYear (cm)	Index No.	2 ndYear (cm)
Complete plot (3 elements)	36.0	100	33.0	100	162	100	156	100	4.95	100	5.25
Non-nitrogen plot	23.5	65	20.0	61	108	67	93	60	5.20	105	5.15
Non-phosphorus plot	30.5	85	26.0	79	147	91	102	65	525	106	4.45
Non-potash plot	28.5	79	30.0	91	135	83	132	85	5.15	104	4.45
Non-fertilizing	26.0	72	13.0	39	102	63	60	39	4.70	95	5.10

Source : Ueda (1962)

Remarks : Applied amounts of fertillzers per 100 m2 ; 7.35 kg. Ammonium sulphate (N: 1.5 kg); 3.38 kg. Super phosphate of lime (P2O5 ; 1.5 kg) 1.24 kg. Potassium sulphate (K2O ; 0.56) ;

Locality : Muko machi, Kyto

TABLE - 45 : PAPER, PULP, BOARD MILLS AND THEIR INSTALLED CAPACITY AS ON 01.01.1990

Particulars	Category	No.of Mills	Installed capacity (mt yr-1)
News print/pulp	-	5	3,00,000.00
Rayon grade pulp	-	1	1,96,250.00
Paper grade pulp	-	-	40,000.00
Pulp and paper mills with capacities from 10000 to 20000 mt	II	30	14,57,300.00
5000 to 1000 mt	III	24	37,91,000.00
2000 to 5000 mt	IV	87	7,28,640.00
Less than 2000 mt	V	107	3,61,720.00
Others		57	87,469.00
Total		315	67,62,379.00

TABLE - 46 : CLOSED PAPER UNITS

Category	No. of closed	Capacity lost (million mt yr-1)
I	9	0.316
II	4	0.061
III	13	0.109
IV	25	0.073
V	24	0.046
	75	6.260

TABLE - 47 : PRODUCTION PATTERNS OF PAPER AND PAPER BOARDS*

Year	Writing & printing	Packing & wrapping	Paper Board	Special paper	Total
1984	0.657	0.452	0.219	0.042	1.370
1985	0.720	0.495	0.240	0.046	1.501
1986	0.758	0.521	0.253	0.048	1.580
1987	0.806	0.554	0.26	0.051	1.680
1990	0.921	0.613	0.298	0.079	1.901

* Figures in million

TABLE - 48 : CURRENT DEMAND AND OUTPUT OF WOOD (MILLION CU M)

Category	Need in 1980	Need in 2000	Additional
Fuelwood	188.600	225.000	36.400
Timber	22.720	46.755	24.035
Pulpwood	4.175	17.695	13.520
Bamboos	4.274	7.005	2.731

TABLE - 49 : RAW MATERIAL REQUIREMENT FOR PAPER AND PAPER BOARD

Year	Capacity (million t)	Production capacity dependent on forest requirement utilization (million t)		Air dry of material (million t)
		80%	70%	
1981	1.816	1.453	1.017	2.848
1986	2.200	1.760	1.232	3.450
1991	2.810	2.240	1.568	4.390
1996	8.500	2.800	1.960	5.488
2000	4.250	3.400	2.380	6.664

TABLE - 50 : COMPARISON OF PULP AND PAPER MAKING CHARACTERISTICS OF PLANTATION BAMBOO WITH HARDWOOD SPECIES

Species	Active altali as Na_2O (%)	Pulp yield (%) Unbleached	Physical strength properties of unbleached pulp				Bleach-ability Test C12 Consumption (%)	Pulp yield (Bleached) (%)	Physical strength properties of bleached pulp			
			Brust factor	Tear factor	Breaking length (km)	Folding endurance			Brust factor	Tear factor	Breaking length (km)	Folding endurance
1	2	3	4	5	6	7	8	9	10	11	12	13
Plantation bamboo (Bambusa bambos)	19	48.80	44.0	68.9	6.41	140.0	10.49	45.0	40.0	63.8	4.38	122.0
Eucalyptus tereticornis	19	43.65	40.5	56.7	6.20	178.0	9.61	38.5	37.4	51.5	4.89	160.0
Acacia decurrens	20	54.32	33.2	48.3	6.20	130.0	7.51	49.3	30.4	2.3	5.10	110.0
Acacia arabica	22	50.62	38.7	52.5	5.90	160.0	8.08	47.0	33.5	40.5	3.21	140.3
Erythronia suberosa	20	49.65	34.7	47.8	5.90	265.0	10.85	39.3	30.3	41.5	4.20	249.0

The value given are the results of three independent observations, no much variation in the results observed. So the mean average were given.

TABLE - 53 : DISTRIBUTION OF BAMBOO WORKERS ACCORDING TO EDUCATIONAL STATUS

Status	Sathya-mangalam	Chikkara-sampalayam	Vada valli	Kemban aicken palayam	Kalli patty
Illitrate	3	-	1	8	6
Primary	2	15	17	8	14
Secondary	10	5	2	4	-

TABLE - 54 : DISTRIBUTION OF BAMBOO WORKERS ACCORDING TO MONTHLY INCOME GROUP

Status	Sathya-mangalam	Chikkara-sampalayam	Vada valli	Kemban aicken palayam	Kalli patty
< 400	2	3	-	-	2
400 - 500	4	5	9	10	4
500 - 600	10	10	7	5	8
600 - above	4	2	4	5	6

TABLE - 55 : DISTRIBUTION OF BAMBOO WORKERS ACCORDING TO CASTE

Status	Sathya-mangalam	Chikkara-sam palayam	Vada valli	Kemban aicken palayam	Kalli patty
Vellala gounder	11	8	4	6	4
Kuravar	6	10	9	9	11
Valluvar	3	2	7	5	5

TABLE - 56 : CONSUMPTION PATTERN OF BAMBOOS IN INDIA

S. No.	Uses	Consumption (%)
1.	Pulp	35.00
2.	Housing	20.00
3.	Non-residential construction	5.00
4.	Rural uses	20.00
5.	Fuel	8.50
6.	Packing, including baskets	5.00
7.	Transport	1.50
8.	Furniture	1.00
9.	Other wood working industries	1.00
10.	Others, including ladders, staff, mats etc.	3.00

Source : (Suri & Chauhan, 1984)

TABLE - 57 : GENERAL USE OF BAMBOOS IN INDIA

Usage	Species
Constructions	Bambusa polymorpha, B. balcooa, B. blumeana, Cephalostachyum pergracile, Dendrocalamus membranous, D. hamiltonii, D. giganteus, D. longispathus, D. strictus, Gigantochola nigrociliata, Melocanna baccifera, Neohouzeaua dullooa, Teinostachyum beddomei.
Thatching and Roofing	Bambusa bambos, B. tulda, B. polymorpha, Dendrocalamus strictus, chimonobambusa falcata, Oxytenanthera monoadelpha.
Walling of native huts	Simbambusa elegans
Lance staves	Dendrocalamus strictis, Oclandra travancorica, O. scriptoria
Tea estates	Pseudostachyum polymorphum
Walking sticks	Arundinaria armata, Dendrocalamus strictus
Basket making	Arundinaria intermedia, Bambusa nutants, B. pallida, B. bambos, B. khasiana, Chimonobambusa falcata, Dendrocalamus longispathus, No.Indocalamus wightiana, Neohouzeaua helferi, N. dulloa, Oxytenanthera ritcheyi, Thamnocalamus spathiflorus.
Bows and arrows	Bambusa bambos. Cephalostachyum cepitatum, Dendrocalamus strictus
Cooking utensils	Cephalostachyum pergracile

Usage	Species
Mats	Arundinaria intermedia, Bambusa nutants, B. terea, B. tulda, B. pallida, B.bambos, B. blumeana, B. hamiltoni, Indocalamus wightianus, Teinostachyum dullooa.
Hedges	Bambusa nana, Dendrocalamus giganteus
Water containers crops	Bambusa pallida, Dendrocalamus sikkimensis, D.giganteus, D. hookeri
Agricultural implements	Dendrocalamus strictus, Oclandra tranancorica All thinner varieties
Seed food	Bambusa bambos, Cephalostachyum pergracile, Dendrocalamus strictus
Furniture	Dendrocalamus strictus
Fodder	Arundinaria racemosa, Chimnobambusa densifolia, Cephalostachyum peraracile, Dendrocalamus strictus, D. sikkimensis.
Floats for timber; rafts	Bambusa bambos, Dendrocalamus hamiltoni, Oclandra scriptoria
Fencing	Indocalamus wightianus, All bambos
Tool handles	Dendrocalamus strictus, Ochandra travancorica
Fishing rods	Arundinaria amabilis, Chimnobambusa falcata, C. khasiana, C. intermedia, Dendrocalamus strictus.
Hookah pipes	Chimnobambusa falcata, Themnocalamus spathiflorus
Shooli for food	Bambusa tulda, B. bambos, Dendrocalamus giganteus, Sinobambusa elegans

Usage	Species
Punting poles	Oxytenanthera stocksii
Sericultural industry	Bambusa bambos, Dendrocalamus stricuts
Chicks for door & windows	Bambusa bambos, Dendrocalamus strictus
Pipes	Teinostachyum griffithii
General utility	Bambusa bambos, Dendrocalamus strictus, D. hookeri
Haystack stabilizers	Dendrocalamus strictus
Horticultural pursuits	Bambusa bambos, Dendrocalamus strictus
Cremation, coffins	Bambusa bambos, Dendrocalamus strictus
Cradles	Bambusa bambos, Dendrocalamus strictus
Scaffolding	Bambusa bambos, Dendrocalamus strictus
Cartyokes	All large sized have and solid bambos
Ladders	Bambusa bambuos, Dendrocalamus stricuts
Musical instruments	Dendrocalamus strictus, Arundinaria sp.
Protection during grain pounding	Bambusa bambusos and all large sized bambos
Country tiles	Bambusa bambos
Stakes for foresters	All bamboos

Pan trays Neohouzeua dullooa

Usage	Species
Seed drills	Dendrocalamus strictus
Containers for administering to animals	Bambusa bambos
Ornaments	Bambusa vulgaris, Cephalostachyum pergrcile
Boat roofs	Bambusa bambos
Pea roofs	Thanmnocalamus spathiflora
Trellises	Bambusa bambos, B. blumeana
Afforestation of river, soil conservation and shelter belts and wind trees -	All bamboos

(Source : Mauria and Arora, 1988)

tochondrial function, regulation of metabolic pathways, plant signaling pathways, and plant-microbe interactions. The amount of information incorporated into this volume is immense, yet the genius of the presentation is that each process is described in clear, simple models upon which the supporting details may be fit to yield an up-to-date understanding of the process. Despite the potential for information overload, the reader is not overwhelmed with minutiae to the point of perplexion as to how the facts may be fit together into a conceptual framework. That is not to say that conflicting or unexplainable data is glossed over or omitted, but rather it has been effectively used to point out where additional research is required.

When considering the effect of pH gradients, the size of the proton necessitates that the main focus deals with processes at the cellular and biochemical levels and this book is principally aimed at those levels. Yet the authors have been careful to include consideration at the whole plant level and interactions between whole plants and their environment. In fact, this volume nicely concludes with a consideration of plant species distribution in relation to pH of the soil and water. Thus, we get to move beyond the individual plant into community structure and view the role of pH at the ecological level as well.

For a volume with 28 contributors, the editor has maintained a remarkable consistency in terms of organization and style throughout the work. Each chapter flows from one to the next without the jarring stylistic differences one frequently encounters with such a collaborative volume, and cross-referencing among chapters has effectively avoided undue repetition while further highlighting the global nature and intricate webs of pH regulation. The figures have been kept to the essential minimum and are generally serviceable black and white line drawings that emphasize essential points of regulation. In a couple cases, however, the reproduction quality is low giving the appearance of figures that have been photocopied one time too many and in the case of one Northern blot, the bands are so washed out that the figure fails to substantiate the narrative convincingly. On the other hand, the color images generated by confocal microscopy are well-done and are especially illustrative of how the technique can be used to study subcellular pH gradients and relate them to cellular processes. Overall, this volume is a good resource for active researchers and advanced students in plant physiology and crop science. The seminal research substantiating each chapter is thoroughly referenced and would serve as an excellent bibliographic source for anyone wishing to delve into a particular aspect in more detail.

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Physiology of Bamboo. P. SHANMUGHAVEL and K. FRANCIS. Scientific Publishers (India), PO Box 91, Jodhpur, India. 2001. Hardcover, 154 pp., $30.00. ISBN 81-7233-274-2.

Bamboo is an integral part of the cultures of South and South-East Asia and represents an important natural and renewable resource. Bamboos, which are woody tree-like grasses, have a long history as an exceptionally versatile and widely used resource in many cultures. They have been called "poor man's timber" and "the-cradle-to-coffin-plant" and provide many of the resources needed for human existence.

India has developed a substantial pulp and paper industry that relies on bamboo as a source of fiber. Although the Indian subcontinent is a rich center for diversity for bamboo with some 130 species occurring on over 10.5 million hectares or 12% of the forested land, the bamboo resource in its natural habitat is dwindling rapidly because of population growth, over exploitation, shifting cultivation practices, and extensive forest fires.

This scenario is true throughout South and Southeast Asia where the seemingly endless supplies from vast natural bamboo forests have declined into a situation of acute scarcity. In the face of this state of affairs, many governments have had to restrict or ban the harvest and exportation of bamboo. With the deterioration of natural bamboo stands, future availability of this vital resource can only be assured by developing sustainable production systems to provide adequate quantities of bamboo to meet the needs of industry and other traditional users of this versatile natural product.

Despite the importance of this crop on a worldwide scale, much of the scientific information available on bamboo is incomplete and scattered among various sources. In writing the *Physiology of Bamboo*, the authors have attempted to address this deficit by pulling together available published research reports reflecting current knowledge on the cultivation and physiology of this important crop. Their efforts have resulted in a comprehensive volume that focuses on bamboo cultivation and management, including bamboo growth and development, anatomy, biomass production and allocation, nutrient composition, and the dynamics of nutrient cycling within the plantation ecosystem. Given the urgency to establish a sustainable basis for bamboo production as a plantation crop as opposed to a non-renewable resource extracted from imperiled natural systems, this publication provides base-line data and a foundation for the establishment of extensive bamboo cultivation, as well as further research into this neglected species.

The *Physiology of Bamboo* is not intended for the casual reader or bamboo hobbyist, the book is a serious scientific work in which the authors have meticulously and painstakingly assembled numerous tables documenting nearly every conceivable parameter relating to the physiological, morphological, and biodynamic aspects of the growth and development of bamboo and the performance of bamboo in the forest ecosystem. The book is well researched but may be tedious for some readers because of the colloquial English employed at times.

Following an introduction (Ch. 1) and general description of common bamboos (Ch. 2) and the cultivation and management of bamboo (Ch. 3), the chapters on the growth and development of the crop (Ch. 4) as well as biomass production and allocation (Ch. 7) have thoroughly quantified crop performance over time and will provide planners, as well as production managers with valuable data with which to assess biological productivity and economic performance. The information provided on the anatomy (Ch. 5) and physical and mechanical properties (Ch. 6) of bamboo is essential in promoting expanded usage of this already versatile plant. For the proper understanding and management of bamboo in the forest ecosystem, knowledge of nutrient composition, levels, and the dynamics of nutrient cycling in bamboo is critical. While substantial information is available on the mineral nutrition of a wide range of temperate and tropical crops, relatively little information has been available on the nutrient dynamics of bamboo. The information collected in this work (Ch. 8, 9, 10) contributes substantially to the knowledge base vital to the development of a fertility program that will sustain the produc-

tivity of the soil while supporting large-scale plantation production systems.

Although the versatility of bamboo as a unique raw material for a diversity of applications is well known, its largest use may be for the manufacture of paper. Chapter 11 describes the fiber characteristics, chemical analysis, and pulp and paper making characteristics of bamboo. In the final chapters of the book (Ch.12, 13, 14), the authors suggest methodologies to help guide future research on bamboo, document comparative studies of biomass accumulation and productivity of other forest ecosystems, and provide an extensive bibliography of existing bamboo research.

The *Physiology of Bamboo* is a timely and valuable monograph on the existing research into the cultivation and physiology of bamboo. This handy little book will provide an excellent reference for those interested in the study and production of bamboo.

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Plant Breeding. S. DANA. Partha Sankar Basu, Naya Udyog, 206, Bidhan Sarani, Kolkata, 700 006 India. 2001. Paperback, 240 pp. ISBN 81-85971-87-0.

For several thousand years, farmers have been altering the genetic makeup of the crops they grow. Beginning with individual plant selections suitable for domestication by the first farmers, human selection for desirable features, such as early maturity, shorter stature, or larger seeds has changed domesticated plant species compared with their wild relatives. Major advances in plant breeding followed the rediscovery of Mendel's laws. Breeders brought their new understanding of genetics to the traditional techniques of self-pollinating and cross-pollinating plants. Plant restructuring in wheat and rice by means of dwarfing genes laid the foundation for the Green Revolution that has benefited millions of people worldwide. Continuing with the use of biotechnology to introgress genes of interest, plant breeding is justly one of mankind's most productive occupations contributing to human welfare. Even so, only a limited number of standard plant breeding texts are available. Therefore, we picked up this book with alacrity hoping that it would integrate classical and modern plant breeding approaches.

The 16 chapters in this book aim to provide a broad, general introduction to principles of plant breeding for undergraduate students. It does not cover aspects related to breeding of individual crops. The first chapter on history of plant breeding restricts itself to prehuman food gatherers and the beginnings of agriculture 13 000 years ago. This is an utter disappointment since it does not cover any aspect of plant breeding history. Many of our modern crops were developed in diverse geographical areas by people who lacked an understanding of the scientific basis of plant breeding. But they were able to enforce selection pressures to derive plant ecotypes for various uses. Therefore, a chapter on the origin and domestication of crops is important to understand breeding of a crop. This chapter begins with Vavilov's eight primary centers of origins, Harlan's noncenters, and concludes with a section on changes in plant traits under domestication. There is no information on how understanding origin and domestication can help breeders to achieve their goals. The chapters on genetical basis of plant breeding and quantitative inheritance provide the basics of Hardy-Weinberg law, components of variation, and an extensive treatment of diallel analysis. These chapters are an unexciting treatment of population genetics and do not provide details on its application. The chapter on reproductive systems reads like a glossary, with single sentence explanations for various modes of reproduction. This section could have been improved with a discussion on implications for the choice of breeding methodology. The chapter on selection begins with Fisher's fundamental theorem of natural selection, briefly treats types of selection, continues with factors affecting selection response, pure line theory, and ends abruptly with marker-assisted selection. The chapter "Breeding Methods" is exhaustive and is well organized. It includes methods for selection of parents, handling segregating generations for self- and cross-pollinated crops, population improvement methods, and methods for apomictic crops.

The chapter, "Plant Genetic Resources," includes exploration, collection, documentation, and conservation. A detailed treatment of the establishment of genebanks for food crops at International Agricultural Research Centers and on-line availability of crop descriptor and evaluation data would have added value to this chapter. The chapter on heterosis is very short and should have been included as a section under "Breeding Methods." It includes explanations for the phenomenon of heterosis and hybrid vigor. No details are provided on the use of cytoplasmic male-sterile lines, development of inbreds, testing of hybrid combinations, or methods of hybrid seed production. The chapter on wide crosses introduces the subject in a glossary style by mentioning pre- and post-zygotic isolation mechanisms and methods to overcome such barriers. The chapter, "Ideotype Breeding," takes rice as an example and gives ideal characters for various plant parts. It does not discuss the influential concept of *Super Rice* with low tillering but sturdier stems and with a larger number of grains per panicle, developed by the International Rice Research Institute. The chapter on breeding for resistance is big and does a good review of resistance to diseases, insect pests, and abiotic stresses. However, it does not discuss incorporation of abiotic and biotic resistances by means of molecular markers.

From the early fifties through the seventies chromosome engineering using allopolyploidy and anueploidy was akin to the biotechnology of today. The introgression of yellow rust resistance from *Aegilops comosa* into wheat by the 5-B suppression system of *Ae. speltiodes*, transfer of leaf rust resistance from *Aegilops umbellulata* to wheat, and use of balanced tertiary trisomics for breeding barley hybrids are some of the elegant examples of the use of cytogenetics in plant breeding. Unfortunately, information in the chapter on polyploidy and chromosome manipulation is presented in an abstract form and does not relate the phenomenon's significance in plant breeding. Mutation breeding has been used to derive several useful cultivars (website http://www-infocris.iaea.org/, verified 27 February 2003, provides details). Much progress is being made combining molecular markers and mutation breeding approaches. The chapter, "Mutation Breeding," provides no details on the choice of mutagens and screening methods to identify mutational events. The chapter on somoclonal variations and transgenics is a good review of this subject area. Notable effort was made by the author to do an extensive list of achievements of transgenics in plant improvement.

The last chapter considers cultivar release and registration procedures and is an inadequate attempt at describing seed regulatory systems in India. The exemplary cultivar testing systems and release procedures implemented by the All India

PHYSIOLOGY OF BAMBOO

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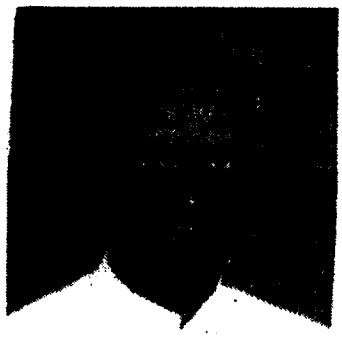

Dated : 22.02.2001

FOREWORD

Bamboo represents one of the world's greatest natural wealth and a good renewable resource. The dwindling availability of natural bamboo forces one to think seriously as to how this problem could be overcome. The present crisis in sustained availability can be ensured only by raising extensive bamboo plantations. At present, lot of efforts are being initiated to improve the cultural and agronomic practices and techniques that would enhance bamboo production. In this context, it is heartening to note that Dr. P. Shanmughavel and Dr. K. Francis have tried to present some relevant and important points to the physiology of bamboo in their book entitled "PHYSIOLOGY OF BAMBOO". This book will certainly help the researchers, scientists, students and farmers engaged in the field of bamboo. I would like to congratulate the authors for their painstaking contribution.

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PREFACE

Forests, the gift of nature, yield innumerable forest products which comment a high demand. At present due to indiscriminate destruction of forests, the demand is not adequately met by the natural resources. The fibre products derived from bamboo is such an example. With the dwindling of natural bamboo, quality rayon, paper and other fiber product industries are left with only alternative methods of cultivation. In the absence of natural bambbo vegetation, the current plantation technique is conventional with little scientific background. Many plant species designated as agricultural crops have been documented with monographs. However, cultivation of bamboo as a plantation crop and its physiology are not documented as a monograph on physiology of bamboo which need is fulfilled through this publication.

Dr. P. Shanmughavel
Dr. K. Francis

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CHAPTER - 1

INTRODUCTION

Bamboos represent one of the world's greatest natural and renewable resources. It is integral to the culture of South and South-East Asia. Every country has its own indigenous bamboo flora. Over 75 genera and 1250 species are reported to occur in the globe. (Soderstrom and Ellis, 1987) India perhaps has the world's richest resources of bamboo, claiming about 130 species occurring over an area of 10.05 million hectare. This is about 12.8 per cent of the total forest area of the country. (Sharma, 1987) Evenso bamboo resource in their natural habitat is dwindling, due to over exploitation, gregarious flowering, shifting cultivation practices and extensive forest fires. A sustained availability can be ensured only by elaborate bamboo cultivation.

Efforts are therefore, directed towards the cultural and agronomic techniques which will boost bamboo production so that raw material in sufficient quantity can be made available to farmers, rural households and industries. Yet very little about its biology, embryology, cytology, physiology of flowering, ecology, silviculture and utilization are known which are receiving a high priority in the research activities of bamboo specialists (Tewari, 1987).

Work done in India and elsewhere on growth and productivity of bamboo is very meagre on plantation crop. Studies on the effect of container size on seedling growth in a number of species point to the positive effect of using large containers (Chacko and Jayaraman, 1988). Performance of *Bambusa bambos* seedlings in nursery are

attempted (Kondas *et al.*, 1973; Suzuki and Narita, 1975; Kim *et al.*, 1976 and Patil and Patil, 1988). Observations on growth and development of forest bamboos were studied (Tomar, 1963; Hasan, 1975 and Carcallus *et al.*, 1988). The productivity of bamboos on unit area basis (t/ha) in plantations is almost meagre in India.

The importance of physical properties of soil for tree growth has been stressed. (Auten, 1945) Foliar analysis is accepted as a more reliable means than chemical soil testing for determining the nutrient needs of the trees and nutrient availability levels in the soil (Heiberg and White, 1950). There are known sources of variations which need to be considered in relation to the availability of the nutrients, the age of the stands and influence of the environmental factors (Pande *et al.*, 1989). Hence, the study on nutrient distribution in biomass components of various trees is essential which is meagre in relation to plantation bamboos.

Circulation of nutrients also plays a very important role in forest plantation ecosystems. Nutrients are circulated relatively large amounts within the ecosystems. Much of the nutrient uptake by trees is returned to the soil by way of litter fall, but an appreciable amount is retained by the bole, bark and branches which are usually harvested and removed from the site (George, 1977). This loss of nutrient is greater with intensive utilization of fast growing species. The study on biological productivity and cycling of nutrients becomes therefore necessary with a view to maximize the productivity from limited forest areas (Pande *et al.*, 1989). The recycled nutrient from decomposing forest litter is one of the main sources for maintaining the growth of forest tree. Although, studies have been carried out on the litter production and its decomposition in tropical and temperate forests (Bray and Gorham, 1964 and Staaf and Berg, 1981) the required information on plantation bamboo is limited (Fu Maoyi *et al.*, 1988).

During the last few decades, bamboo has become a major source of raw material for the Indian Pulp and Paper Industry. During extraction of bamboo from the forest, no definite age for cutting is maintained. Rather bamboos of different age groups are extracted indiscriminately. As a result pulping in the mixture of bamboos of different age groups may form in heterogenous cooking, resulting inferior quality of pulp (Bose *et al.*, 1988). With a view of overcoming these problems, several researches were conducted to observe the influence of age on pulp yield and quality.

In view of its multi-dimensional importance in various spheres, a thorough understanding of several factors related to the growth of bamboo, its productivity, biomass, anatomy, litter production,

nutrient uptake and return and its general place and role in the dynamics of the forest ecosystem has become necessary. Much of the information is however, very incomplete and that which available is still scattered and less accessible. Also in addition to this already published literature there are of course those current findings from on-going research efforts, often reflected in reports of parochial or very limited circulation that frequently take quite a long time to emerge in the so called 'open' literature. Hence, concerted efforts have been made to make more of the recent developments available and to highlight the importance of work on bamboos by means of a handy book. This book focuses the importance of bamboo cultivation, management, productivity, anatomy, properties, nutrient dynamics, nutrient cycling, pulp and paper characters and also discusses the methodology to study the bamboos.

CHAPTER - 2

GENERAL DESCRIPTION OF *BAMBUSA BAMBOS*

Bambusa bambos (L.) Voss, Besch, Pflanzen deutsche Gaerten 2 : 1986; Druce in Rep. Bot. Exch. 4 : 608, 1917; Merril in Trans. Amer., Philos. Soc. 24 : 81, 1935; Soderstrom in J. Amer. Bamboo Soc., 6 : 6-7, 10, 1985; Dajun and Saho-Jin, Bamboos of China 98. 1987; Bennet and Gaur, Thirty seven Bamboos : 19, 1990.

Arundo bambos. L., Sp. Pl. 81, 1753.

Bambos arundinacea Retz., Obs. 5 : 24. 1789.

Bambusa arundinacea (Retz) Willd., Sp. Pl. 2 : 245, 1797; Munro in Trans. Linn. Soc. Lond., 26 : 103, 1868, Gamble, Ann. Roy. Bot. Gard. Cal. 7 : 51. 1896 and in Hook.f., Fl. Brit. India., 7 : 395, 1897; Varmah and Bahadur in Indian For. Rec. (n.s.) Bot 6 (1) : 2 : 1980.

Vernacular/local names : Assami-Kotoba; Bengali-Baroowa, Behor-Ketwa, Manipuri-Seneibi; Marathi-Katang bamboo. Orissa-Daba; Telugu-Mulkas Vedura; Tamil- Perumungel.

English Name : Spiny Bamboo

Distribution : *Bambusa bambos* is one of the most importance bamboos found throughout India (Kondas, 1982). In Maharashtra they occupy a total of 12,757 sq. Km. area (Desai and Subramanian 1980). The annual harvest of this species from Karnataka is 1,60,000 tonnes (Prasad and Gadgil 1980). In plains of Manipur this is the

most widely distributed and the most abundant species (Janmejay Singh 1986). This species is commonly cultivated in plains.

Description : Very densely tufted bamboo with curving branches. Culms usually bright green shining usually 15 to 30 m high, 15 to 18 cm diameter. Nodes slightly swollen. Internodes between 20 to 40 cm long, thick walled; branches develop from all nodes form the base upwards, lower branches spreading and with recurved spines; spines usually three. Culm-sheath usually 15-35 x 18-30 cm, blade upto 10 cm long adaxial surface with dense dark brown to black-hairs. leaves lanceolate to linear, highly variable in size. Leaf sheath ligulate. Inflorescence on enormous panicle, branchlets spicate with loose clusters of about 5 pale spikelet, rachis variable, spikelet lanceolate, sessile, consisting at 2 to 1 or no empty glumes, 3 to 7 flowers, the lower ones hermaphrodite, the upper flowers male only, finally 1 to 3 imperfect flowers, stamens exerted, drooping, filaments slender, anthers yellow, obtuse, ovary elliptic oblong, glabrous except at the tip. Style short, glabrous, soon dividing into 3 long plumose stigma. Seeds caryopsis oblong 4 to 8 cm long. Smooth, formed by the base of the style, always surrounded by the persistent glume and palea. Embryo-conspicuous.

Flowering : There are two types of flowering (John *et al.*, 1994) 1-gregarious; 2-sporadic. The latter group of plants revert to vegetative growth and the former perish after flowering. Gregarious flowering of this bamboo has been recorded in the year 1866 from Kanara, Coorg, Malabar, 1869 from Satpuras; 1874 to 1884 from Kanara, Belgaum, Dharwar in Karnataka, 1881 Kumaon hills (UP) 1896 from Walayar forest, Coimbatore; 1912 to 1915 from Wynaad, Kollegal, Coimbatore; in 1913 from Bihar and Orissa and 1913-15 from Coorg. Gadgil (1980) reported that gregarious flowering during 1977-79 from Coorg district of Karnataka. Latest flowering in Ganjam district of Orissa in 1976 was after a full cycle of 10 years (Das 1976). Gaur (1989) opines the period of flowering cycle as 30-45 years. However, in Thailand, it flowers every year (Anantachote, 1987). Blatter (1931), after analyzing all the flowering records available from its natural zone, concluded that its flowering cycle is 30-34 years and also points out that at Dehra Dun where it has been planted it has a cycle of 45 years.

Uses : The strength, straightness, lightness combined with extraordinary hardness, range in size, abundance, easy propagation and the short period in which bamboo attains maturity, is best suited for a variety of purposes. Even today, bamboo continues to find new uses, in paper making, rayon industry, construction, architecture, engineering technology, handicrafts, foods and medicine.

GENERAL DESCRIPTION OF *DENDROCALAMUS STRICTUS*

Dendrocalamus strictus (Roxb.) Nees in Linnaea 9 : 476. 1894 Munro in Trans. Linn. Soc. Lon. 26 : 147; 1868; Gamble Ann. R. Bot. Gard. Cal. 7 : 78; 1896 and in Hook. F. Fl. Brit. Ind. 7 : 404. 1897 Camus, Les Bambusees 152; 1913. Bennet and Gaur. Thirty seven Bamboos 61. 1990.

Bambusa stricta Roxb. Corom. Pl. 1.58 t. 80.1798.

English name : Male bamboo

Vernacular name : Bengali-Karail; Gujarath-Nakr bans; Kan-Kiri bidiru; Marathi-Male bamboo, nanvel; Oriya-Salia; Tamil-Kalmungil; Telugu-Sadanapa veduru; Tripura-Lathi bans.

Distribution : Widely distributed in India, in semi-dry and dry zone along plains and hilly tracts usually upto an altitude of 1000 m; also commonly cultivated throughout the plains and foot hills.

Description : Deciduous densely tufted bamboo : culm 8 to 16 cm high, 2.5 to 18 cm in diameter, pale blue green when young, dull green or yellowish when old, much curved above half of its height, nods somewhat swollen, basal nodes often rooting, lower nodes often with branches, internodes 30 to 45 cm long, thick walled. Culm sheaths variable, leaves linear, lanceolate, ligule very short, inflorescence a large panicle of large dense globular heads, 4 to 5 cm apart, rachis rounded, smooth, spikelet spinescent, usually hairy, the fertile intermixed with many sterile small ones, 7-5 to 12 x 2.5-5 mm with 2 to 3 fertile flowers, empty glumes 2 or more ovat, spinescent many nerved, flowering glumes ovate, ending in a sharp spine surrounded by ciliate tufts of hairs, palea ovate or obovate, emarginate, lower ones 2 keeled, ciliate on the keels and 2 nerved between them, uppermost not keeled often nearly glabrous, 6 to 8 nerved, stamen long exerted. filamets fine, anthers yellow, shortly apiculate, ovary turbinate, stalked hairy above and surmounted by a long style ending in a purple feathery stigma, seeds caryopsis, brown shining, ovoid to sub-globose, pericarp coriaceous.

Flowering : Apart from the gregarious flowering after long intervals, sporadic flowering can be seen every year in different parts of the country. The flowering cycle for the Garhwal outer Himalyan tract is 20 to 60 years. In north Kanara this flowered sporadically spread over 12 to 13 years. Gregarious flowering was reported from different parts of the country (Bennet and Gaur 1990).

Uses : This is one of the two most important bamboos in India (Kondas 1982). It is found suitable for reclamation of ravine lands (Shrivastava and Qureshi 1986). In India it is extensively used as a raw material in paper mills and also for a variety of purposes including construction purposes.

CHAPTER - 3

CULTIVATION AND MANAGEMENT

Bamboos are found in large forest areas growing throughout Asia and Pacific area. Although a major part of the requirements for the bamboo is presently being met from natural stands, the increasing demand for housing and construction can be provided for in the future only from the extended plantations on marginal soils (Coxi-and Utisols). Extensive plantations of bamboos, mostly *Bambusa bambos* have recently been grown in several regions of India to meet the increasing demand for long fibre pulping material (Shanmughavel 1995).

Bamboo, which are giant woody tree-like grasses, have a long history as an exceptionally versatile and widely used resource. Bamboo is known variously as 'poor mans' timber, 'the cradle to coffin plant' and 'green gold'. Bamboo has and still does provide the materials needed for existence. It is also an eminently renewable resource. Under suitable conditions this crop displays prodigious rates of growth. Some species can produce culms 40 m high and 30 cm diameter in only four months. The total length of culms produced by a giant bamboo clump over its life time can well exceed 15 km. It has two kinds of flowering behaviours, firstly a sporadic and irregular flowering and secondly periodical gregarious flowering. The gregarious flowering is followed by the death of the clump and varies from 20 to 75 years depending upon the locality, management practices and biotic interferences (Shanmughavel, 1995).

A complete bamboo plant consists of three morphologic structures the leafy aerial part (the culm) and two underground parts (the rhizome and the roots). For successful growth all these structures must develop. Failure in the development of any of these phases leads to complete failure. Most bamboo species of commercial importance form clumps (a cluster of culms). The new seedlings (the seedlings resembles a blade of grass) produces a rhizome, which develop new rhizomes that produce culms. The number of new rhizomes may vary from one to many. Depending upon the production of rhizomes, bamboos are classified into three types :

(1) *Monopodial* - the rhizome having one bud at each node which develops monopodially every year.

(2) *Sympodial* - the apex of the rhizome having nodes but no buds does as the monopodial type and protruding out of the ground and growing into a culm. In the following year, the bud on the basal part of the culm develops into a short rhizome which protrudes out of the ground to make a secondary culm, thus forming a clump.

(3) *Intermediate* - intermediate between monopodial and sympodial.

Over exploitation associated with growing human population, destruction of tropical forests and new demands on this resource for industrial uses, especially by the pulp and paper industry, has resulted in the wide-scale decimation of the bamboo stocks. From vast forests of bamboo in south and south-east Asia at the beginning of this century, we are left with the current situation of acute scarcity. Many countries have been forced to severely restrict and in some cases even ban the harvesting and exporting of bamboos. The present crisis of sustaining the availability of bamboo can be ensured only by raising bamboo plantations.

NURSERY MANAGEMENT PRACTICES AND TRANSPLANTING

Since bamboo seeds possess a short period of viability (a few days to 1 month), seedlings from tissue culture should be employed for raising bamboo plantations. A nursery area of 10 x 5 m should be prepared in the field and filled with a mixture of soil and sand (3 : 1). The seedlings may be pricked out from the polythene bags when about 7 cm in height. About 25 to 30 seedlings can be planted in 1 m^2 of raised nursery bed. Watering should be done 2-3 times a day and care should be taken to avoid over saturation. Nursery beds may provided with a thatch to protect the seedlings from direct and excess sun light. The seedlings in the nursery uprooted carefully and should

be transplanted to the field. The seedlings may be planted at 6 x6 cm spacing with 277 seedlings ha^{-1}. The transplanted seedlings need be watered every 2 hrs regularly in the morning and evening. Weeding should be done as and when required. After 1 year the plantation should be adequately irrigated at 15 day intervals. Care should be taken to avoid water logging. The plantation should be protected against damage by rodents and grazing and browsing animals.

PRODUCTION OF CULMS

All the transplanted seedlings may produce rhizomes. The culm buds may emerge with the onset of early rains and grow rapidly. They reach full height within 90 days. An unusual rain during the winter months may induce emergence of new culms, but they do not grow successfully like those produced in rainy season. The culms may very tender during the growing period. It has been observed that the daily height growth of culm is approximately 33 cm. The internodes may be wrapped with sheaths. In the first month the culms may lose their sheath and may develop side shoot buds. These start to elongate during the second month. The maximum length of side shoot may reached upto 150 cm. In the third month leaves may arise from side shoots. Then the culms may continue to change in density. After this they would start changing in colour. The new culms may formed along the outside edge of the clump later on tend to grow inwards and get entangled among the older culms.

A brief cultivation and management of bamboos are as follows :

(1) Seedlings obtained from tissue culture methods should be used (the bamboo seeds possess short period of viability and also the procurement of seeds is difficult). The large sized polythene bags (20 x 30 cm) are filled with clean soil, sand and manure in the ratio 2 : 1 : 1. About 15 to 20 plants are planted in each polythene bag. Watering should be done 2 to 3 times a day and care is to be taken to avoid over saturation. Seedlings were kept in polythene bags for one month.

(2) The nursery should always be raised in shades.

(3) In each polythene bag 15 to 20 seedlings may be planted. The number of rhizomes may vary from 4 to 5. These set of rhizomes is not singled out or sorted but the entire thing in one polythene bag should be planted in the field.

(4) The seedlings in the nursery should be uprooted carefully and need be transplanted to 45 x 45 x 45 cm pits in the fields at a spacing of 6 x 6 m (one week prior to planting the pits should be

treated with 0.01% aldrex and 0.05% bavistin to prevent termite and fungal attack respectively.

(5) Planting should be completed before the monsoon get active.

(6) To provide better initial growing environment to the seedlings, the upper halves of the pits should be filled with a mixture of 25 g vijay complex 17 : 17 : 17 per pit while lower halves were filled with the original soil.

(7) Protection against damage by rodents, grazing and browsing animals should be carried out.

(8) The profuse watering is essential but over watering should be avoided.

(9) The transplanted seedlings may produces rhizomes which would develop new rhizomes that produce lateral culms which are the chief causative for the total biomass yield. The number of culms developed from the rhizome totally constituted to a clump.

(10) At a given site the production of new culms may depended on the culms of the previous year, the degree of congestion and the clump age. The average annual recruitment of culm generally increased year after year. The culms produced during first year may be shorter in length and smaller in diameter, but culms from subsequent years will be longer in length and bigger in diameter.

(11) The rhizome development is not peripheral as generally believed. Rhizomes may develop in any direction and the culms may appear anywhere in the clump provided over head light is available for the emergence of the culm. It is only in congested clumps that the new culms appear to grow at the periphery. The new culms can even be seen in the middle of the clump.

(12) New culms are produced each year. Older culms should therefore be harvested each year. Culms older than two years took little part in the growth of new culms. Retention of culms older than two years is therefore not needed for the production of new culms. Culms older than three years are fully mature for the desired end use. The following rates should therefore be applied for getting high productivity of the desired quality of culms.

(a) all bamboo culms three years older should be harvested.

(b) harvesting should preferably be done each year.

(c) where congestion has already set in, the congested culms should be removed even if it produces leaves in the current year culms.

(d) where the young culms are twisted from the top they should be cut so that the new culms grow freely.

(e) no felling operations should be carried out from July to October.

(f) mounding or heaping earth around the bamboo clumps should be carried out after every felling of culms.

(g) bamboo clump should in no case be clear felled. The clear felled clump generally degenerate into a bushy farm.

The above mentioned cultivation and management practices can be used as a guidelines for taking up large scale plantations of bamboo on a suitable land.

CHAPTER 4

GROWTH AND DEVELOPMENT

1. GROWTH OF SEEDLINGS

The seedling bamboo may resembles a blade of grass. Seedlings should be watered daily and death does not appears to be due to onset of the dry season. Bamboos (the monocotyledons) may have very different root system. The seedlings may develops a underground rhizome system, which may carries a dense mat of thin usually undivided adventitious roots, which may show no secondary thickening and may be replaced by new ones as they die off in course of time. From the rhizome, in due course, culms of successively larger size may be sent up.

2. DEVELOPMENT OF RHIZOME

A scaly rhizome (or) underground stem will be produced from the base of the seedling plant and may after growing vertically downwards to a short distance, may curves up again and may appears as a small culm. Further rhizome sections will be develop in succession from the first and may follow the same course penetrating deeper into the soil till the optimum depth of about 0.5 m may reached and may sending up successively larger culm. Full sized culms will be produced after 2-5 years depending on species and conditions. The rhizomes may often branch two (or) more club shaped lengths each may sending in a culm (or) culm bud developing from

Plate 1. Origin of FLAT rhizome from which culm bud appear.

buds (Plate 1) on a single older length. It may appears to be unusual for culms to be produced from rhizome sections more than 2 (or) 3 seasons old growth accordingly it normally tends to be peripheral, but rhizomes sometimes may grow towards the centre specially if conditions may unfavourable. In the species in which the rhizomes may extends some distance before sending up new culm, the culms themselves may well spacedout and individual plants often cannot be distinguished from their neighbourhood e.g. in *Melocanna baccifera*, but in many of the more important species notably *Dendrocalamus strictus*, the rhizome sections may be short and culms may remain close together in a clump.

3. CULM GROWTH AND DEVELOPMENT

There may be three phases of growth and development of culm viz., culm elongation (first phase) which on nearing completion may triggers thorn emergence (second phase) and finally leaf appearance (third phase). The first phase may commences with "Komali" which means tender culm (30 to 40 cm high) may completely be covered by sheaths with no internodes seen outside and may looking funny like a

shoots with no internodes seen outside and may looking fully like a foolscap (Plate 2). This stage may lasts for about ten days and growth will be extremely slow. After the initial period of slow growth the

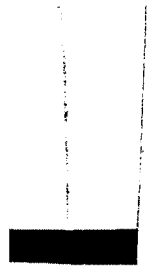

Plate 2. Growth of culm (20 cm)

elongation will takes place in spurts of increasing rates and may reaches the peak lasting a few days and then falls rapidly marked by leaf appearance (Plate 3 and 4) culm elongation may over in 70 to 90 days depending on the length of culm. The emergence of thorns (in *Bambusa bambos*) may commences from the 25th to 50th day of "Komali" appearance and will be completed in about 135 days. Leaves may appear on the 60-90th day and the culm may becomes fully leafy in about 150 to 180 days. The supple culm may hardens on account of silica deposition in the walls. It is December-January by the time all these biological consolidation will take place in the next six months.

Plate 3. Falling off the sheaths

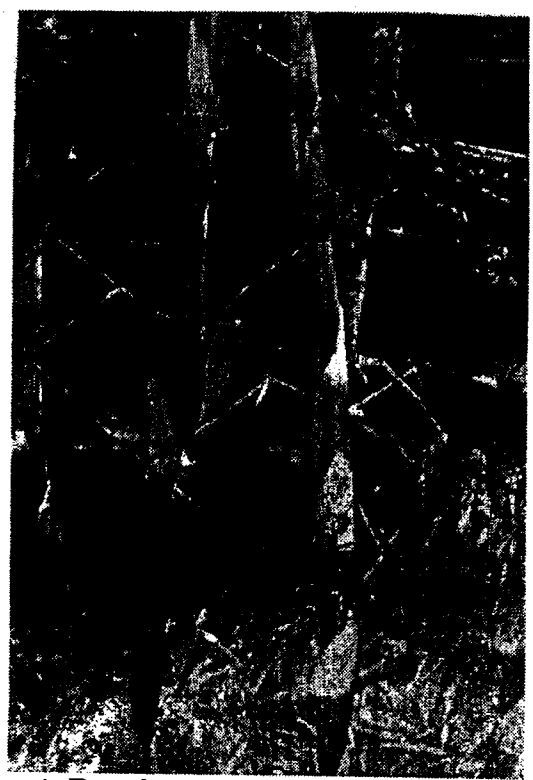

Plate 4. Development of leaves on branches

In the coming June-July-August the cycle of vegetative activity may resumes with the development of "daughter" rhizomes. Rarely even before the current-year-culm may attains full development the rhizome buds may develop pre maturely but they may fail very soon. Years may bearing more sprouts (or) "Komali" (on-year) and those may bearing fewer (off-year) usually may occur alternately every year. While in a good sprouting year new culms may be large in size, in a year when sprouts are less in number, the size of new culms does not become large. This, however does not appear to be of a permanent hereditary nature, but it can be controlled by fertilizing and other means. All culms produced from the single seedling unit together may constituted to a clump (Plate 5).

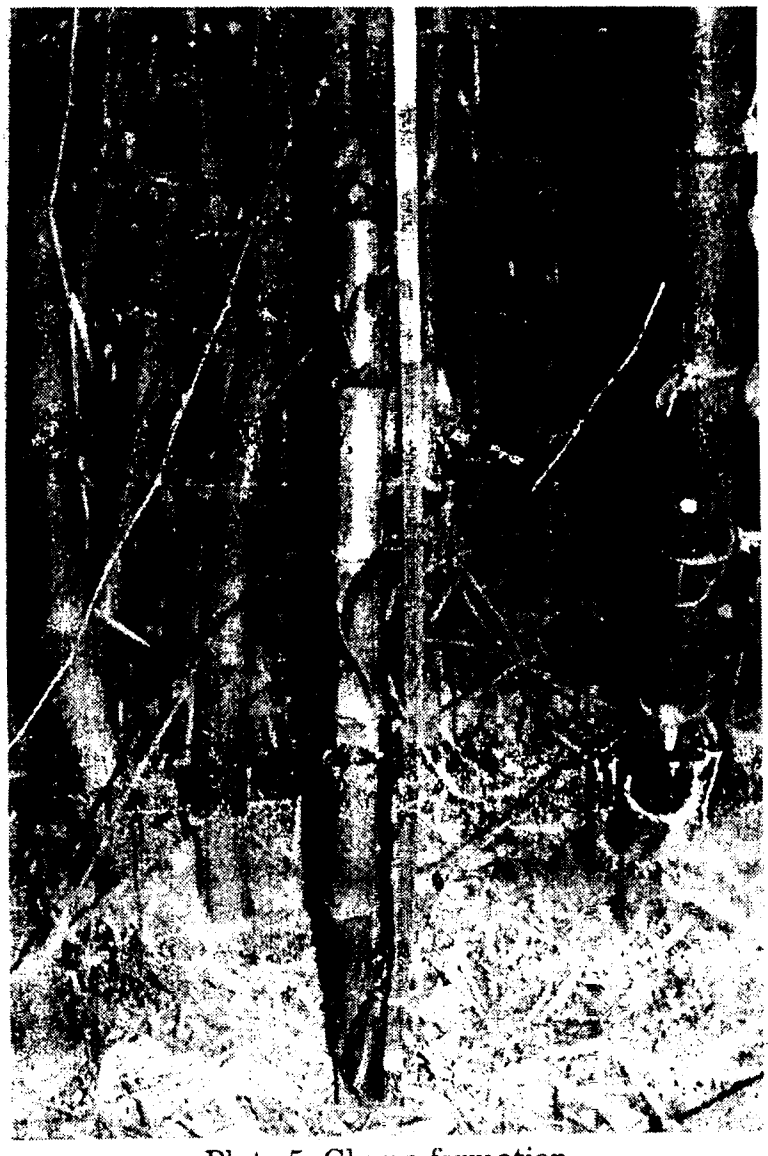

Plate 5. Clump formation.

4. ANNUAL RECRUITMENT OF CULMS

The productivity of bamboo will be assessed by the number of new culms produced annually. At a given site, the production of new culms may mostly depended on, the degree of congestion, clump age and rainfall of the previous year. In India, new culms may generally appear during the rainy season. An unusual rain during the winter months may induce the emergence of new culms.

Generally when bamboo seedlings are planted almost all seedlings produced culms in the first year. Subsequently next year the *Bambusa bambos* species may produces only 5 culms per clump in the first year. The number of culms may gradually increased in the subsequent years and became maximum (17 culms) in the 6th year of clump age. Number of culm production may be slowly decreased from the 7th year and may only 4 in the 10th year of clump age. Similar results may also observed by Banik (1988) in four other *Bambusa* species, namely *Bambusa vularis, Bambusa balcooa, Bambusa longispiculata* and *Bambusa tulda* and *Melocanna baccifera* at the Forest Research Institute, Bangladesh. Cumulative 4 total culms produced in the clumps of all these *Bambusa* species upto to 6th year of age may leads to crowded condition due to short (7-12 cm) neck pachymorph rhizome system. This crowded and congested condition may created a scarcity of room for the new emerging culms and may also increased competition among them for survival (Kondas, 1981, Banik, 1988; Shanmughavel, 1995). Probably due to this reason culm production may subsequently decreased from the 6th year in the *Bambusa* species. Anonymous (1975) observed in a clump of *Bambusa vulgaris* planted in Dandeli, India that the culm production may higher upto the 4th year after planting and then decreased in the subsequent years. However, in the case of *Bambusa bambos* the culm production may increased upto 10 years (Kondas, 1981).

In *Melocanna baccifera* the average production of culms may be 2.5 in the first year and from third year the number may increased rapidly to 12.5. Culm production may also rapidly increased in the subsequent years and may reaching 35.7 after the 10th year of culmp age. Unlike, other clump forming bamboos *M. baccifera* may have under- ground pachymorph rhizomatous system with strongly elongated (1.0-1.5 m) neck (Banik, 1988). Owing to this rhizome nature the species may produces culms at varying intervals in all directions may forming a diffuse and open type of clump condition (Watanabe, 1986) which may accommodate the space required for the increased number of culm production in the subsequent years after plantation. Probably due to this reason the rate and pattern of clump girth expansion in *M. baccifera* may differs from those of other

Bambusa species. Othman (1992) reported that the annual recruitment of culms may decreased from the third year clumps of *Gigantochloa scortechnii* at Forest Research Institute, Malaysia. *Gigantochloa scortechnii* plantation may consists of 33.6%, 42.2% and 24.2% of 1, 2 and 3 year old culms after planting respectively.

5. CULM HEIGHT AND DIAMETER

Culms of all bamboo species may complete their growth within 2 to 3 months after the emergence of sprouts from the ground, but their diameter and height do not increase after the growth may over (McClure, 1967; Banik, 1980; Ueda, 1981, Shanmughavel, 1995). It may observed that in all bamboo species that the culms emerged in the first year after plantation may short in length and narrow in diameter at breast height (Table 1). Culm produced in subsequent years may be distinctly taller and wider in diameter then those produced in the past years and such trend may continued upto 6 years in *Bambusa bambos,* 5-6 years in *B. longispiculata* and *B. tulda* and 7 years in the case of *B. vulgaris* and *B. balcooa*. After these periods clumps of these *Bambusa* species did not produce any taller and wider culms in the subsequent years. Clumps of *Melocanna baccifera* may produced taller as well as wider (with increased diameter) culms in the subsequent years of planting and the trend may distinctly rapid upto four years of age. Culms produced in the later years (upto 10 years of study) may also be taller and wider but at a comparatively reduced fate. Similarly, culm diameter may also not much different in the subsequent years after the fourth year of clump age (Banik, 1988). Similar results may reported in other bamboos *Bambusa bambos* and *B. vulgaris* (Kondas, 1981) *Gigantochloa scortechnii* (Othman, 1992).

6. MONTHLY RECRUITMENT OF CULM

From the bamboo plantation, a set of fifteen clumps may be selected randomly from the sixth year plantation for the assessment of monthly, recruitment of culms (Shanmughavel, 1995). Every month, the number of newly sprouted culms and their survival need be recorded. The observation may continued for full one year. The monthly recruitment of culms for the year 1993 may revealed that maximum recruitment of culms may took place during September-November which is the monsoon season. An average of 17 culms may be produced from one clump (Table 2). However, their survival rate may reduced drastically due to white ants and other physiological causes. Monsoon dependency of the plantation may be prominent, since the maximum recruitment of culms seems to be monsoon dependents rather than intermittant showers.

Table 1. Stand characteristics of Bambusa bambos plantation

Characteristics	Year									
	1	2	3	4	5	6	7	8	9	10
culms /ha	1250	2250	3000	3500	4000	4250	3250	2750	1500	900
DBH (cm)	2.13 ± 0.22	3.13 ± 0.22	4.2 ± 0.25	4.9 ± 0.20	6.2 ± 0.25	8.2 ± 0.25	5.4 ± 0.12	4.1 ± 0.20	2.8 ± 0.25	2.5 ± 0.29
Height (m)	1.44 ± 0.37	3.26 ± 0.20	9.6 ± 0.76	21.6 ± 1.49	27.3 ± 0.52	29.0 ± 0.56	20.5 ± 1.0	16 ± 1.20	8.5 ± 1.15	7.4 ± 1.05

The culm produced from 1st to 10th year plantation crop was counted per hectare. They were estimated for DBH and height. The values expressed are average from three independent experiments.

Table 2. Monthly recruitment of culms/clump

Month	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S
January	3	–	4	–	4	1	1	1	2	–	3	1	4	1	4	1	3	1	3	1	4	1	3	–	4	–	1	–	1	1
February	4	1	4	–	2	–	2	–	3	1	4	1	3	1	3	1	4	1	4	1	4	–	4	1	3	1	2	1	2	1
March	3	1	3	1	3	1	3	–	4	1	3	–	4	–	5	1	2	–	3	–	3	–	5	2	4	1	3	1	3	1
April	2	–	2	–	3	–	2	1	6	1	2	–	3	–	4	–	3	–	4	–	–	–	6	1	5	2	–	–	4	1
May	2	–	2	–	4	1	4	1	3	–	3	–	4	–	3	–	4	1	3	1	–	–	3	–	–	–	–	–	–	–
June	3	–	4	2	4	2	6	2	2	–	4	2	3	2	2	1	5	2	4	2	3	1	4	1	3	1	4	2	3	1
July	5	–	5	2	6	3	8	3	6	3	6	3	4	2	4	3	8	4	6	4	4	1	6	3	7	3	5	1	6	3
August	4	1	5	2	7	3	6	2	8	3	9	4	6	2	6	3	9	3	9	3	5	2	8	3	5	3	6	3	4	2
September	8	4	6	3	8	2	6	4	7	4	6	3	4	1	6	3	3	1	7	1	6	3	8	4	6	4	4	3	6	4
October	6	3	4	1	4	2	3	1	3	–	4	1	6	4	3	2	4	2	4	2	6	4	6	3	3	3	2	1	4	3
November	6	3	3	1	3	1	3	–	4	1	3	1	4	2	6	2	3	1	3	1	4	2	4	1	4	1	3	1	3	1
December	5	1	4	2	3	1	2	2	3	1	3	1	3	2	5	2	2	1	2	1	3	1	3	–	3	–	4	2	4	2
Total culms	16		14		17		17		15		17		18		19		17		16		15		19		20		15		20	

Fifteen clumps were randomly selected from the sixth year plantation for the assessment of monthly - recruitment of culms and their survival were recorded. It revealed the maximum recruitment of the culms took place during September-November, which was the monsoon season. An average of 17 culms were produced from one culm, during the year, 1993.
C - Number of newly sprouted culm; S - Survival.

Table 3. Daily height growth of *Bambusa bambos*

Days	CLUMP NUMBER														
	1			2			3			4			5		
	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA	Height	DBH	BA
2 (cm)	12	–	4	25	–	3.5	21	–	4.5	44	–	3.5	46	–	4.5
4	20	–	–	28	–	–	34	–	–	61	–	–	65	–	–
6	33	–	–	34	–	–	45	–	–	1.01	–	–	99.5	–	–
8	52	–	–	63	–	–	64	–	–	1.49	–	–	1.4	–	–
10	69	–	–	78	–	–	93	–	–	2.09	–	–	1.5	–	–
12	76	–	–	1.05	–	–	1.17	–	–	2.27	–	–	1.7	–	–
14 (m)	1.02	3.5	4.5	1.44	3.5	4.5	1.51	3.5	5.5	2.5	4.5	5	2.3	4.5	5.5
16	1.52	–	–	1.91	–	–	1.94	–	–	3.1	–	–	2.7	–	–
18	1.9	–	–	2.5	–	–	2.0	–	–	4.0	–	–	3.0	–	–
20	2.0	–	–	2.7	–	–	2.7	–	–	4.2	–	–	3.3	–	–
22	2.2	–	–	3.5	–	–	3.8	–	–	4.4	–		3.5	–	–
24	2.5	–	–	4.0	–	–	4.2	–	–	4.5	–	–	3.7	–	–
26	2.6	–	–	4.2	–	–	4.5	–	–	4.5	–	–	3.9	–	–
28	2.8	–	–	4.4	–	–	4.7	–	–	4.7	–	–	4.2	–	–
30	3.4	–	–	5.0	–	–	5.0	–	–	5.2	–	–	4.9	–	–
32	4.0	–	–	5.5	–	–	5.7	–	–	5.7	–	–	5.5	–	–
34	4.5	–	–	6.2	–	–	6.3	–	–	6.6	–	–	5.9	–	–

Table 3 contd...

Table 3 contd...

													6.5	–	–

Table 3 contd...

36	5.5	–	–	6.7	–	–	6.8	–	–	7.0	–	–	6.5	–	–
38	5.7	–	–	7.0	–	–	7.2	–	–	7.2	–	–	7.0	–	–
40	6.0	–	–	7.0	–	–	7.2	–	–	7.2	–	–	7.0	–	–
42	6.0	–	–	7.0	–	–	7.2	–	–	7.2	–	–	7.3	–	–
46	6.5	–	7	7.4	5.5	7.5	7.9	6.5	6.9	7.6	5.5	6.5	8.0	5.5	7.5
52	8.0	–	–	8.2	–	–	8.9	–	–	8.6	–	–	8.7	–	–
55	9.5	–	–	9.7	–	–	9.5	–	–	9.6	–	–	9.8	–	–
57	10.7	–	–	11.5	–	–	11.7	–	–	11.5	–	–	11.9	–	–
59	12.0	–	–	12.5	–	–	12.9	–	–	12.7	–	–	13.0	–	–
61	14.5	–	–	14.7	–	–	15.0	–	–	15.5	–	–	15.5	–	–
64	16.0	–	–	16.7	–	–	17.5	–	–	17.0	–	–	17.9	–	–
66	18.5	–	–	18.0	–	–	18.5	–	–	18.0	–	–	19.5	–	–
70	19.0	–	–	20.5	–	–	19.5	–	–	20.5	–	–	21.5	–	–
72	19.9	7.5	9.5	21.5	6.5	7.5	21.5	8	8.5	22.0	6.5	8.5	22.0	6.5	7.5
75	20.5	–	–	22.0	–	–	22.0	–	–	–	–	–	–	–	–
77	21.0	–	–	22.5	–	–	22.5	–	–	–	–	–	–	–	–
79	21.4	–	–	22.7	–	–	22.8	–	–	–	–	–	–	–	–
82	22.0	–	–	23.0	–	–	23.0	–	–	–	–	–	–	–	–
84	22.3	–	–	23.4	–	–	23.5	–	–	23.5	–	–	24.3	–	–
86	23.0	–	–	23.4	–	–	24.0	–	–	24.0	–	–	24.0	–	–
88	23.5	–	–	24.0	–	–	24.3	–	–	24.0	–	–	24.0	–	–
90	23.5	–	–	24.0	–	–	24.0	–	–	24.2	–	–	24.4	–	–

Table 3 contd...

Table 3 contd...

92	23.5	–	–	24.0	–	–	24.0	–	–	24.7	–	–	24.5	–	–
94	24.0	–	–	24.0	–	–	24.4	–	–	24.3	–	–	24.0	–	–
96	24.5	–	–	24.0	–	–	24.7	–	–	24.7	–	–	24.5	–	–
98	27.5	–	–	24.5	–	–	27.5	–	–	27.8	–	–	28.0	–	–
100	28.0	8.5	10	27.5	8	9.5	28.0	8.5	10.5	28.0	8	10	28.0	8.5	10.5
105	28.0	–	–	28.0	–	–	28.0	–	–	28.0	–	–	28.0	–	–
107	28.0	–	–	28.5	–	–	28.0	–	–	28.0	–	–	28.5	–	–
150	28.5	–	–	28.5	–	–	28.5	–	–	28.5	–	–	28.5	–	–
180	29.5	–	–	28.5	–	–	28.0	–	–	28.5	–	–	28.5	–	–
195	29.5	–	–	28.5	–	–	28.5	–	–	28.5	–	–	28.5	–	–
210	28.5	8.5	10	28.5	8	9.5	28.5	8.5	10.5	28.5	8	10	28.5	8.5	10.5

Fifteen clumps were selected at random from the sixth year plantation, and identified with paint marking. New culm sprouting from the clumps were taken for growth measurement. On alternate days, the height of each culm was measured and only after reaching 1.37 m height, the diameter at breat height (DBH) was recorded. All observation were made for the basal area girth, DBH, and growth in height, on all culm. The values expressed are the average of 3 clumps.

Table 5. Pattern of allocation of biomass in growing *Bambusa bambos* (kg/culm)

Days	DBH	Height	Basal	Leaf		Branch		Culm		Total above ground biomass	
	(cm)	(m)	area (cm)	Fresh weight	dry weight	Fresh weight	dry weight	Fresh weight	dry weight	Fresh weight	dry weight
75th day	7.5	20.5	9.5	–	–	4.800	2.400	19.400	9.700	24.200	12.100
96th day	7.5	24.5	9.5	–	–	5.400	2.700	47.300	15.200	35.800	17.900
105th day	8.5	28.0	10.0	0.700	0.350	7.600	3.800	62.800	23.650	55.600	27.800
120th day	8.5	28.5	10.0	0.836	0.460	9.272	5.100	83.900	34.540	72.908	40.100
135th day	8.5	28.5	10.0	1.290	0.710	11.282	6.500	87.840	46.190	97.000	53.400
150th day	8.5	28.5	10.5	1.610	0.820	13.200	8.580	114.200	57.100	102.650	66.500
165th day	8.5	28.5	10.5	1.892	0.910	18.770	9.390	114.300	57.100	134.850	67.400
180th day	8.5	28.5	10.5	1.895	0.920	18.430	9.380	11.840	57.200	134.220	67.500
195th day	8.5	28.5	10.5	1.890	0.950	18.430	9.350	11.840	57.100	135.150	67.450
210th day	8.5	28.5	10.5	1.895	0.900	18.430	9.100	11.840	57.000	135.150	67.000
219th day	8.5	28.5	10.5	1.895	0.946	18.430	9.381	1.840	57.113	135.150	67.444

The culm developed in the 6th year with its components was harvested from the field on specific days mentioned above. The wet weight was determined in the field. They were dried at 103 ± 2°C and the moisture free components were used to determine the dry weight.

7. DAILY HEIGHT GROWTH

In order to study the daily height growth of plantation bamboo, from three hectare 15 clumps may be selected at random from the sixth year plantation and may identify with paint marking. Number of culms presented in these selected culmps should be counted. New culms sprouting from the selected clumps may taken for growth measurements. In each clump, five newly sprouted culms may marked with paint, totalling 150 observations. On alternate days the height of each culm may be measured and only after reaching 1.37 m height, the diameter at breast height (DBH) may be recorded. All observations should be made for the basal area girth, DBH and growth in height on all culms (Table 3). In *Bambusa bambos*, culms may reached their maximum height in about 4-5 months analogous to *Gigantochloa levis* and *G. ligulata* (Othman, 1992). Under cultivation, the average daily height growth may reach approximately 30.0 cm at sixth year which may vary considerably between species depending on the soil conditions and mineral nutrition (Raghavan, 1964; Kondas, 1973). The maximum growth per day (24 hours) found to be in the vigorous growing period. According to the records, the growth per day was 91.3 cm by *Bambusa bambos* observed at Kew Garden in England (1855) and was 88.0 cm by *Phyllostachys edulis* which Shibata (1898) observed at Koishikawa Botanical Garden in Tokyo. Ueda (1981) recorded the growth of 119 cm and 121 cm per day in *Phyllostachys edulis* and *Phyllostachys reticulata*. Such a remarkable growth could never be seen in any other plants.

8. PATTERN OF BIOMASS ALLOCATION IN GROWING BAMBUSA BAMBOS

The pattern of biomass allocation can be studied from the young sprouted bamboo (culm) of 12 cm height. At one week interval, these young bamboos need be felled and their height should be recorded. Each young bamboo after fully differentiated with culm, branch and leaves, the whole unit should be felled and these components may be separated individually. Their fresh weight may determined in the field and all the sub samples should be brought to the laboratory filling in plastic bags. They should be oven dried to remove all moisture at 103 + 2°C to a constant weight. From moisture free oven dry weight of these samples, the dry weight of each tree component and their total weight may be calculated.

Table 4. Growth and biomass of culms

Days	Height	Fresh weight (kg/culm)	Dry weight (kg/culm)	Remarks
2nd day	12 cm	0.500	0.150	Just sprouting
10th day	76 cm	1.633	0.490	
20th day	2.2 m	3.300	0.990	
32nd day	4.5 m	4.625	1.850	Sheaths starts to withering
52nd day	8.0	13.125	5.250	Branch buds visible
64th day	16.0	19.625	7.850	At each node, three branch bud clearly visible
75th day	20.5	24.200	12.100	Branches continues to increase in length
96th day	24.5	35.800	17.900	Leaf bud develop on branches
105th day	28.0	55.600	27.800	Leaf develops
120th day	28.5	72.909	40.100	Leaf develops
135th day	28.5	97.090	53.400	Leaf develops
150th day	28.5	102.650	66.500	
165th day	28.5	134.860	67.400	
180th day	28.5	134.875	67.500	
195th day	28.5	135.160	67.450	
210th day	28.5	135.160	67.450	
219th day	28.5	135.160	67.444	

The growth of the newly developing culm in the 6th year plantation was followed from a 6 year old clump starting from initiation till maturation on the days indicated above. Along with the growth measurement of the culm with its branches and leaves were brought to laboratory, dried and weighed. The values expressed are the average of three indenpendent experiments.

There can be a significant increase in culm weight, as it attained maturity. There may be a 12 fold increase in culm weight from its initial sprouting (0.150 g) to a month (1.850 kg/culm). This weight may increased as the branches and leaves began to develop. The total oven dry weight of the culm with its components from its sprouting showed there may be considerable variation between dry weight of sample culm and their components. In young sprout the moisture loss should be 60-70% up to the development of branch bud. After initiation of leaves, the moisture content should be 50-60%. Later the moisture may ranged from 33-45. The biomass allocation to each components in growing *Bambusa bambos* showed that, 80-85% of biomass may allocated to culm, 15-20% of branch and only 1% found in leaves (Table 4 and 5).

CHAPTER - 5

ANATOMY

Bamboo is a fascinating plant for the many thousands of bamboo lovers in temperate climates, both in Western Europe and North America. But for billions of people in Asia, South-America and also Africa, bamboo is an integral part of their daily life requirements, and its use from the cradle to the coffin is an often cited proverb. Bamboos are used for countless different purposes. They grow abundantly in many parts of the tropics and subtropics. Often only certain species are preferred for distinct uses, whereas other species are neglected. Restrictions which exist in processing and utilization of the many bamboo species are often related to unsuitable properties. The "bamboo wave" which is presently obvious in many parts of the world with larger plantation schemes requires also considerations about the latter utilization, which determines much the economy of any action program. A thorough understanding of the relations between structure, properties, behaviour in and during processing and subsequent product qualities is necessary for promoting the utilization of bamboo. In the following, a brief outline is given of the many inter-dependencies.

1. Shoot Growth

Bamboo is a giant grass produces a primary shoot without any later secondary growth. The elongation of a culm results from the expansion of its individual internodes and starts at the lower internodes. In the beginning of differentiation, the whole internodes

consists of an intercalary meristem. In its upper part it differentiates into the various cell types which elongate, while the lower part retains its meristematic activity. With the elongation of the cells the meristematic activity moves down to the base of the internode, it finally ceases to divide, and the lower cells elongate until the internode has fully developed. Between the internodes a horizontal plate exists which forms the diaphragm and the nodal division.

Whereas, in the internodes all cells are axially oriented, the nodes provide the only transverse interconnection. They also have a lock-like function for which the cell elements of the internodes become modified by branching.

A bamboo culm is developed by extension of the internodes until its full height of 10-30 m within a period of 3-4 months. This means that bamboos are the fastest growing plants. Taking into account their diameter of 20 cm or more, an enormous biomass must be produced and transported from the stored energy in the rhizomes and by the younger culms within a short period of time. The growing culm hardly possesses leaves for the production of its own energy required for the extension.

2. Gross anatomical structure

The bamboo culm shows a rather simple anatomical construction and among the about 700 species, difference are rather small, and may be considered as insignificant, compared to the large structural heterogeneity of the about 25000 timber species. Also growth conditions have apparently no significant effect on composition and structure of the culm. But ageing, as mentioned later, induces some strucutural changes.

The gross anatomical structure of a transverse section of any culm internode is determined by the shape, size, arrangement and number of vascular bundles. They are clearly contrasted by the darker coloured sclerenchymatous tissue against the parenchymatous ground tissue. At the peripheral zone of the culm the vascular bundles are smaller and more numerous, in the inner part larger and fewer. Within the culm wall the total number of vascular bundles decreases from bottom towards the top, while their density increases at the same time.

The tissue of a culm consists of parenchyma cells and the vascular bundles, which are composed of vessels, sieve tubes with companion cells and fibres. The total culm comprises of about 50% parenchyma, 40% fibre and 10% conducting tissues (vessels and sieve tubes) with some variation according to the species.

The percentage distribution of cells shows a definite pattern within the culm, both horizontally and vertically. Parenchyma and conducting cells are more frequent in the inner third of the culm wall, whereas in the outer third the percentage of fibres is distinctly higher. In the vertical direction the amount of fibres increases from bottom to top and the amount of parenchyma decreases.

(a) Parenchyma

The ground tissue of parenchyma cells which are mostly vertically elongated (100*-20 m) with short, cube-like ones interspersed in between. The former are characterized by thicker walls with a poly-lamellate structure. They become lignified already in the early stages of shoot growth but can still be alive in culms older than 10 years. The shorter cells have a denser cytoplasm and thinner walls. The function of these two different types of parenchyma is still unknown.

(b) Vascular bundles

The vascular bundle in the bamboo culm consisted of the xylem with one or two smaller protoxylem elements and two large metaxylem vessels (40-120 m) and the phloem with thin walled unlignified sieve tubes connected to companion cells.

The vessels possess large diameters in the inner part of the culm wall and become smaller towards the outside. These water conducting cells have to function without the formation of any new tissue, as in the case of hardwoods and softwoods with cambial activity. Any interruption of the water transport by suction force of the leaves may be critical and has to be stopped efficiently. Special response mechanisms become active, as well be shown later for the alterations induced by ageing.

Both the metaxylem vessels and the phloem tissue are surrounded by sclerenchyma sheaths. They differ considerably in size, shape and location according to their position in the culm and the species. Some genera have additional fibre bundles which are separated from the vessels by parenchymatic tissue.

For resp. four major types of vascular bundles can be differentiated.

*Type 1 : Consisting of one central vascular strand supporting tissue only as sclerenchyma sheaths semi-open, rsp. open type.

The chinese scientists have differentiated Type 1 into a semi-open type with lateral and inner vascular bundle sheaths linked

together, and an open type with lateral and inner vascular bund sheaths linked together, and an open type with the four vascul bundle sheaths of same size and symmetrically located.

*Type 2 : Consisting of one central vascular strand supporting tissu only as sclerenchyma sheaths. Sheath at the intercellular spa (protoxylem) strikingly larger than other three tight-waist typ

*Type 3 : Consisting of two parts, the central vascular strand wi sclerenchyma sheaths and one isolated fibre bundle (broke waist type).

*Type 4 : Consisting of 3 parts, the central vascular strand with sm sclerenchyma sheaths and two isolated fibre bundles outsi and inside the central strand. (double-broken-waist type).

Some examples

Type 1 alone : *Arundinara, Phyllostachys, Fargesia, Sasa* a *Pseudosasa*

Type 2 alone : *Cephalostachyum, Pleioblastus*

Type 3 alone : *Oxytenanthera Gigantochloa*

Type 3 and 4 : *Bambusa, Dendrocalamus, Guadua*

These basic differences in the anatomical make-up affect al number of properties like density, strength, bending behavio splitting and shrinkage.

The phloem of the vascular bundles consists of large thin wall sieve tubes, among which smaller companion cells are distributed.

These cells have to remain alive and active throughout t lifetime of the culm.

(c) Fibres

The fibres contribute 60-70% of the weight of total culm tissu They are long and tapered at their ends. The ratio of length to wid varies between 150 : 1 and 250 : 1. The length shows considera variation between and within species. Mean values are : *Bambu tulda* 3 mm, *Phyllostachys edulis* 1.5 mm.

Generally the fibres are much longer than those fr hardwoods (1-1.5 mm). Different values have been reported for o and the same species. The reason is mainly due to considera variation of fibre length within one culm.

Across the culm wall the fibre length increase from t periphery towards the middle and decrease towards the inner pa

Along the culm from the periphery towards the middle and decrease the inner part. Along the culm from base to top no remarkable pattern for the fibre length exists expect a slight reduction, whereas a great variation is evident within one internode of up to 100% or more. The shortest fibres are always near the nodes, the largest are in the middle.

Thus the nodal part has a reduced strength due to its shorter fibres and marks the breaking point for the standing culm. In service however, bamboo breaks hardly at the nodes because of a higher fibre portion due to reduced parenchyma and increased lignification. Furthermore, the irregularity of the grain with an interwoven structure provides more shearing strength than the internodes with their axial arrangement of fibre sheaths and bundles embedded in homogenous parenchyma. Test samples with nodes however, exhibit lower bending-, compression- and shear strength, although a higher specific gravity.

The ultrastructure of some of the fibres is characterized by thick poly lamellate secondary walls. The lamellation consists of altering broad and narrow layers with differing fibrillar orientation.

This polylamellate wall structure is present especially in fibres at the periphery of the culm, and their significance for bending properties appears obvious. Thin walled fibres do not have such a lamellation. The occurrence and distribution of such fibres will influence certain properties and processing qualities, so that the detailed studies with technologically superior and inferior bamboo species on the fibre type appear useful.

(d) Outer and inner skin

The culm is protected at the outer and the inner side by a special tissue against loss of water and mechanical damage. The outer part consists of two epidermal cell layers with a high silica content and a cutinization of the walls. The inner layer consists of numerous thick walled parenchyma cells, is highly lignified and shows sometimes a suberized membrane. Any loss of water or penetration by liquids is thus much restricted with consequences for drying the culms and their treatment with preservatives. Pathways are only the cross ends of a culm and to a rather small extent the sheaths scars around the nodes.

(e) Structural changes due to wounding and ageing

Structural changes occur due to wounding and ageing. If a culm is damaged mechanically, the transport functions of the vessels are

endangered. Response reactions of the surrounding parenchyma cells occur, which lead to a blocking of the vessels lumina, either by formation of tyloses or by the production of slime like substances. A browning of the parenchyma indicates the production of phenolic substances. During ageing of culms definite changes occur from its immature stage towards maturation up to dying/death of the culm.

They appear in the first and second year in the form of an additional cell wall thickening of fibres and parenchyma cells as well as by progressing lignification. In older culms vessels and sieve tubes can partly become blocked by tyloses and depositions in vessels and sieve tubes, thus loosing their conductivity, which may cause death of the aged culms. The numerous investigations of strength properties in relation to culm age have mostly shown an increase during the maturation period, but also for consecutive years. Dying culms become brittle and are often bent down and break. The structural/chemical basis for such drastic changes in properties is still much concealed.

(f) Natural resistance and preservation

During the ageing of culms no toxic substances are formed, which constitute in many trees the heartwood with high natural resistance against microorganisms and beetle attack. Bamboo is generally liable toward degradation, but fungi can become active only in humid environments. The attack by the common bamboo bores depends mainly on the starch content as nutritional sources. The amount of starch, changes with the growing season and the ageing of the culm.

Preservation of bamboo respectively its penetrability is another area where anatomical structure is decisive. The culm is covered at its outer and inner side by an impermeable skin. Also the absence of ray cells as radial pathways determine the need for axial penetration through the long and wide vessels. In green condition the natural easy flow of water can be used by so called sap replacement treatment. It is only necessary to fill the vessels with a suitable preservative so that during the following resting period the salt components can diffuse into the surrounding tissue. Treatment time depends much on the vessels area of the bamboo. Generally the metaxylem comprises 6-8% but differences exits between the lower and upper part of a culm and also among species.

CHAPTER – 6

PROPERTIES

The natural distribution of bamboos encompasses mainly the tropical, subtropical and wild temperate zones of the world, both the tropical belt having the maximum number of bamboo species (Mohan and Liese, 1990). By far bamboo is among the most important forest products used by rural communities in the manufacture of cradle to housing components. The demand for this material has increased far beyond its availability, causing over- exploitation and depletion of resources. Even today, bamboo continues to find new applications such as in paper making, rayon industry, construction, architecture, engineering, handicraft, food and medicine. Yet little is known about this fascinating plant, its properties, which are receiving a high priority in the research has been discussed in this chapter.

1. MOISTURE CONTENT

The strength properties of bamboos are influenced by the moisture content of the culm. In the green stage greater differences exist within one culm as well as in relation to age, season and species (Table 6). Young, one year old shoots have a high relative moisture content of about 120-130% both at the bottom and the top; the nodes, however show lower values than the internodes. In culms of 3-4 years the base has higher moisture content than the top e.g. for *Dendrocalamus strictus* about 100% relative moisture content and 60% respectively. Throughout the year the water content changes by

upto 100% according to the dry and wet season, especially in the top region. Different species show different moisture values even at the same location. This variation is closely related to the amount of parenchyma cells present, the site of water storage. The considerable differences in the moisture content of freshly felled culms have to be considered when determing the yield of bamboo expressed by its green weight.

Table 6. Mechanical properties of *Phyllostachys pubscens* in the water saturated air-dry and oven-dry state

Property	Part	Water saturaed	Air-dry	Oven-dry
Bending strength (N/mm^2)	Outer	250	270	370
	Inner	120	144	160
Clearage strength (N/mm^2)	Outer	6	7	8
	Inner	5	6	8
	Whole	6	7	8
Shear strength (N/mm^2)	Whole	9	11	18
	Outer end side	49	63	91
		22	25	37
Janka-Hardnes (N/mm^2)	Inner end side	27	32	66
		13	17	37

The moisture content has a similar influence on the strength as in timber. Generally, in the dry condition the strength is higher than in the green condition. This increase in strength with seasoning is more obvious for younger culms than for older ones. The differences between the air-dry and green condition are sometimes relatively small, especially for bending and cleavage.

2. SPECIFIC GRAVITY

The specific gravity varies from about 0.5 to 0.8 (0.9) g/cm^{-3}. The outer part of the culm has a far higher specific gravity than the inner part. The specific gravity increases along with the culm from the bottom to the top. This can be due to the gradual increase in number and compactness of the fibrovascular bundles which contain more thick-walled fibres at the top. The mechanical properties are correlated with specific gravity.

3. SHRINKAGE

The shrinkage varies from species to species. For example *Schizostachyum lumampao* exhibited the greatest radial (thickness)

shrinkage at 18.73% and *Bambusa vulgaris*, the highest tangential (width) shrinkage at 11.92% which differed significantly from the other species. Radial and tangential shrinkages generally decreased from the bottom to the top, and the decrease was significant for tangential shrinkage. The relatively higher frequency of fibro-vascular bundles, low moisture content and high specific gravity in the thinner culm wall at the top may account for such reduction. The dimensional changes from green to oven-dry condition sometimes lead to collapse which appears merely as shrinkage and is frequently so interpreted. Collapse was observed in specimens obtained from the culms bottom where there are more parenchyma cells and less fibres.

4. MECHANICAL PROPERTIES

Bamboo possesses excellent mechanical properties. They mainly depend on the fibre content and therefore vary considerably within the culm and between species. At the base, for example, the bending strength of the outer part is 2-3 times that of the inner part. Such differences become smaller with increasing height of the culm. With the increasing thickness of the culm wall there is an increase in specific gravity and mechanical strength of the inner parts which contain lesser parenchyma and more fibres, whereas in the outer parts these properties change only slightly. The variation of strength properties is much greater in the horizontal direction than in the vertical direction.

A close correlation exists between specific gravity and maximum crushing strength. It seems that resistance to combustion parallel to the grain is more (or) less uniform and hardly affected by the height of the culm. For bending strength and modules of elasticity, higher values were obtained from the upper part. Bamboo splints with the epidermis downwards have a higher fibre stress, bending strength and modules of elasticity than those with the epidermis upwards. Splints without nodes have about once (or) twice the ultimate tensile strength of timbers such as spruce, pine, oak and beech.

The specific gravity of the nodes is generally higher than that of the internodes due to less parenchyma whereas bending strength, compression strength and shear strength are lower. This is due to irregularity of the grain, caused by the arrangement of cells. The presence of nodes than leads to a remarkable reduction in all strength properties.

Since there are still no standard methods of evaluating the

strength properties of bamboo, as in the case of wood, the results are based on different methods of testing and on widely varying dimensions (*Limaye*, 1952, *Sekhar and Bhartari*, 1960).

The superior tensile strength of bamboo in relation to wood and steel is demonstrated by the following comparison; a steel is bow of a certain quality (SA 37) of 1 cm^2 and 1 m length has weight of 0.785 kg and an ultimate tensile force of approximately 40 KN; a stick from wood with the same length and weight would have a cross section of 13.5 cm^{-2} and a breaking point at 80 KN but one from bamboo with 12 cm^{-2} would resist unto 240 KN; i.e. six times that of stem.

CHAPTER - 7

BIOMASS PRODUCTION AND ALLOCATION

Biomass is the total quantity of organic matter per unit area present in an ecosystem at a given time and may relate to a particular species (a) group of species of a community as a whole. Such biomass studies are important to know the biological productivity and at times to know the economic productivity also and generally biomass is expressed on the basis of oven-dry weight. Therefore, an estimation of dry matter production (biomass), and its allocation in bamboo is described in detail in this chapter.

ORGANIC MATTER IN SAMPLE CULMS

The height, DHB of the culm with its weight and the individual weight of the leaves, branches, culms and rhizome of *Bambusa bambos* for ten years are reported (Table 7-16). There may be considerable differences within the dry weights of sample trees and their components. In most of the above ground components, the moisture loss would be ranged between 50 to 60 per cent upon drying. However, in case of below ground parts i.e. rhizome, it may be 40 to 50 per cent. On an average there may be about 55 per cent moisture loss with all plant components of all ages. The dry weight of all the above ground components (culm, branch, leaf) would increased consistent with increasing age upto 6 years and then declined.

Table 7. Organic matter distribution in 1st year *Bambusa bambos*

S.No.	Sample culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM) Leaf	Branches	Culms	Tota above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
1.	1	1	2.2	2.0	1.4	0.100	0.325	0.550	0.975	0.800	1.775
2.	2	1	3.5	2.0	1.0	0.125	0.400	0.450	0.975	–	–
3.	3	1	3.0	2.0	1.4	0.180	0.350	0.600	1.130	–	–
4	4	1	2.5	2.0	1.8	0.100	0.400	0.750	1.250	–	–
5	5	1	2.5	2.0	1.4	0.150	0.425	0.400	0.975	–	–
6	6	1	3.2	2.0	1.4	0.110	0.300	0.450	0.860	–	–
7	7	1	3.3	2.0	1.4	0.125	0.410	0.600	1.135	–	–
8	8	1	3.5	2.0	1.4	0.190	0.425	0.625	1.240	–	–
9	9	1	3.5	2.0	1.4	0.100	0.350	0.650	1.100	–	–
10	10	1	3.2	2.0	1.4	0.115	0.425	0.500	1.040	0.750	1.790
11	11	1	3.4	2.0	1.4	0.100	0.410	0.700	1.210	–	–
12	12	1	3.0	2.0	1.8	0.150	0.450	0.900	1.500	–	–
13	13	1	3.2	2.0	1.8	0.185	0.400	0.400	0.985	–	–
14	14	1	3.5	2.0	1.8	0.125	0.400	0.800	1.325	–	–
15	15	1	3.5	2.0	1.8	0.150	0.450	0.650	1.250	0.700	1.950

Different components of bamboo such as leaves, branches, culms and rhizome were collected individualy from 1-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2°C for dry weight determination.

Table 8. Organic matter distribution in 2nd year *Bambusa bambos*

S.No.	Sample culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM) Leaf	Branches	Culms	Total above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
16.	16	2	3.9	3.0	3.2	0.250	0.750	2.900	3.900	1.100	5.000
17	17	2	3.9	3.0	3.5	0.225	0.700	3.100	4.025	–	–
18.	18	2	4.0	3.0	3.0	0.300	0.800	2.700	3.800	–	–
19	19	2	4.2	3.0	3.0	0.325	0.950	2.500	3.775	–	–
20	20	2	4.0	3.0	3.4	0.300	0.750	2.900	3.950	–	–
21	21	2	3.8	3.0	3.5	0.300	0.900	3.000	4.200	–	–
22	22	2	3.9	3.0	3.5	0.315	0.850	2.800	3.965	–	–
23	23	2	4.0	3.0	3.0	0.200	0.900	2.400	3.500	–	–
24	24	2	4.0	3.0	3.1	0.225	0.950	2.600	3.775	–	–
25	25	2	4.5	3.0	3.4	0.300	0.750	3.000	4.050	1.700	5.750
26	26	2	3.9	3.0	3.0	0.325	0.800	2.800	3.925	–	–
27	27	2	4.0	3.5	3.4	0.390	0.950	3.700	5.040	–	–
28	28	2	4.5	3.5	3.3	0.375	0.900	3.900	5.175	–	–
29	29	2	4.0	3.5	3.2	0.325	0.800	3.500	4.725	–	–
30	30	2	4.5	3.5	3.5	0.310	0.900	3.500	4.170	1.940	6.110

Different components of bamboo such as leaves, branches, culms and rhizome were collected individualy from 2-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2°C for dry weight determination.

Table 9. Organic matter distribution in 3rd year *Bambusa bambos*

S.No.	Sample culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM)					
						Leaf	Branches	Culms	Tota above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
31.	31	3	4.9	4.0	9.0	0.400	4.100	8.700	13.200	1.500	14.700
32	32	3	4.5	4.0	9.0	0.390	4.500	10.100	14.990	–	–
33.	33	3	4.8	4.0	9.0	0.375	5.500	8.500	14.375	–	–
34	34	3	4.5	4.0	9.0	0.350	6.000	8.900	15.250	–	–
35	35	3	5.0	4.0	9.0	0.400	4.800	9.900	15.100	–	–
36	36	3	5.0	4.0	9.0	0.350	6.000	10.000	16.350	–	–
37	37	3	4.9	4.0	9.0	0.300	7.000	9.900	17.200	–	–
38	38	3	4.5	4.0	9.0	0.390	5.100	10.000	15.490	–	–
39	39	3	4.9	4.0	9.0	0.400	6.100	9.750	16.250	–	–
40	40	3	5.0	4.5	10.5	0.500	5.700	10.800	17.000	1.900	18.900
41	41	3	5.2	4.5	10.5	0.375	6.000	10.500	16.875	–	–
42	42	3	5.5	4.5	10.5	0.380	6.000	10.100	16.480	–	–
43	43	3	5.5	4.5	10.5	0.310	5.500	9.100	14.910	–	–
44	44	3	5.5	4.5	10.5	0.310	6.200	10.200	16.710	–	–
45	46	3	5.5	4.5	10.5	0.390	7.100	9.800	17.290	1.600	18.890

Different components of bamboo such as leaves, branches, culms and rhizome were collected individualy from 3-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2°C for dry weight determination.

Table 10. Organic matter distribution in 4th year *Bambusa bambos*

S.No.	Sample culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM) Leaf	Branches	Culms	Tota above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
46.	1	4	5.8	4.5	20	0.400	8.200	20.000	28.600	2.000	30.900
47	2	4	5.9	4.5	20	0.550	7.800	24.950	33.300	–	–
48.	3	4	5.8	4.5	20	0.600	7.500	25.660	33.700	–	–
49	4	4	6.0	5.0	23	0.450	7.100	29.000	36.550	–	–
50	5	4	6.0	5.0	20	0.500	7.500	22.000	30.000	–	–
51	6	4	5.9	5.0	22	0.490	8.400	27.000	35.890	–	–
52	7	4	6.0	5.0	23	0.500	7.400	29.000	36.900	–	–
53	8	4	6.3	5.0	23	0.590	7.800	28.800	37.190	–	–
54	9	4	6.0	5.0	22	0.600	8.500	27.100	36.200	–	–
55	10	4	6.5	5.0	20	0.600	7.500	25.100	34.200	1.400	38.590
56	11	4	6.5	5.0	20	0.550	7.500	25.600	33.550	–	–
57	12	4	6.0	5.0	22	0.500	8.100	26.900	28.500	–	–
58	13	4	6.5	5.0	24	0.510	7.500	29.200	37.210	–	–
59	14	4	6.50	5.0	23	0.600	7.100	28.100	35.800	–	–
60	15	4	6.0	5.0	23	0.550	8.500	29.200	38.250	1.700	39.950

Different components of bamboo such as leaves, branches, culms and rhizome were collected individualy from 4-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2°C for dry weight determination.

Table 11. Organic matter distribution in 5th year *Bambusa bambos*

S.No.	Sample culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM) Leaf	Branches	Culms	Total above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
61	1	2	5	7.5	6.0	27	0.750	8.200	48.050	2.200	50.850
62	2	2	5	8.0	6.0	26	0.950	7.900	54.850	–	–
63	3	2	5	8.0	6.0	27	0.850	8.100	54.050	–	–
64	4	2	5	8.0	6.0	27	0.800	8.500	58.600	–	–
65	5	2	5	8.0	6.0	27	0.900	8.200	57.500	–	–
66	6	2	5	7.5	6.0	27	0.850	8.700	55.950	–	–
67	7	2	5	8.0	6.0	27	0.850	9.000	60.750	–	–
68	8	2	5	8.0	6.5	28.5	0.950	9.100	52.100	–	–
69	9	2	5	8.5	6.5	27.5	0.900	8.900	52.000	–	–
70	10	2	5	8.5	6.5	27.5	0.900	8.900	51.850	2.750	54.750
71	11	2	5	8.5	6.5	27.5	0.950	8.900	57.900	–	–
72	12	2	5	8.5	6.5	27.5	0.900	8.500	56.400	–	–
73	13	2	5	8.5	6.5	27.5	0.900	8.100	60.050	–	–
74	14	2	5	8.5	6.5	27.5	0.850	9.000	60.850	–	–
75	15	2	5	8.5	6.5	27.5	0.900	8.100	61.700	2.700	64.400

Different components of bamboo such as leaves, branches, culms and rhizome were collected individualy from 5-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2°C for dry weight determination.

Table 12. Organic matter distribution in 6th year *Bambusa bambos*

S.No.	Sample culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM)					
						Leaf	Branches	Culms	Total above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
76	1	6	9.5	8.0	28.0	0.95	10.100	52.100	63.150	2.600	65.150
77	2	6	10.0	8.0	28.5	0.90	8.700	53.800	62.850	–	–
78.	3	6	10.0	8.0	28.5	0.90	9.100	62.200	72.100	–	–
79	4	6	10.0	8.0	28.5	0.95	9.200	57.100	67.250	–	–
80	5	6	10.0	8.0	28.5	1.00	9.500	62.100	72.700	–	–
81	6	6	10.0	8.0	28.5	0.90	8.500	56.000	65.400	–	–
82	7	6	10.0	8.0	28.5	0.95	9.700	54.000	64.650	–	–
83	8	6	9.5	8.5	29.5	1.00	9.100	56.200	66.300	–	–
84	9	6	10.5	8.5	29.5	1.00	9.100	54.100	64.200	–	–
85	10	6	10.5	8.5	29.5	1.00	9.800	61.900	72.700	2.400	75.100
86	11	6	10.5	8.5	29.5	0.85	9.500	57.100	67.450	–	–
87	12	6	10.5	8.5	29.5	0.89	9.700	56.100	66.690	–	–
88	13	6	10.5	8.5	29.5	0.90	9.500	53.000	63.400	–	–
89	14	6	10.5	8.5	29.5	0.90	9.800	59.100	69.800	–	–
90	15	6	10.5	8.5	29.5	0.90	9.500	61.900	72.300	2.800	75.100

Different components of bamboo such as leaves, branches, culms and rhizome were collected individualy from 6-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2°C for dry weight determination.

Table 13. Organic matter distribution in 7th year *Bambusa Bambos*

Sample culm No.	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (cm)	Leaf	Branches	Culm	TAGB	Rhizomes	GTB
							kg/culm			
1	7	6.0	5.5	20.5	0.600	6.400	35.200	42.200	2.400	44.600
2	7	5.9	5.0	20.4	0.550	6.900	36.100	43.550	–	–
3	7	6.5	5.5	20.0	0.590	6.500	36.500	43.590	–	–
4	7	5.0	5.5	20.5	0.650	7.000	37.100	44.750	–	–
5	7	6.0	5.4	20.5	0.550	6.600	38.100	42.250	–	–
6	7	5.5	5.4	20.4	0.490	7.100	35.100	42.690	–	–
7	7	6.5	5.5	20.5	0.500	5.900	35.700	42.100	–	–
8	7	6.0	5.4	20.5	0.650	7.200	36.000	43.805	2.600	46.450
9	7	6.5	5.5	20.3	0.550	6.500	35.100	42.150	–	–
10	7	6.0	5.5	20.3	0.600	6.100	36.200	42.900	–	–
11	7	6.5	5.4	20.5	0.550	5.900	34.900	41.350	–	–
12	7	6.0	5.5	20.5	0.600	5.900	36.100	42.600	–	–
13	7	6.0	5.4	20.5	0.650	6.100	35.000	41.750	–	–
14	7	6.5	5.5	20.0	0.600	6.800	36.700	44.100	–	–
15	7	6.0	5.5	20.0	0.650	6.500	036.00	43.150	2.600	45.750

Different components of bamboo such as leaves, branches, culms and rhizome were collected individualy from 7-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2°C for dry weight determination.

Table 14. Organic matter distribution in 8th year *Bambusa Bambos*

Sample culm No.	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (cm)	Leaf	Branches	Culm	TAGB	Rhizomes	GTB
							kg/culm			
1	8	5.0	4.0	16.5	0.450	5.100	28.500	34.050	2.000	36.050
2	8	5.0	4.0	16.8	0.400	5.500	23.500	29.400	–	–
3	8	5.5	4.3	17.0	0.500	6.600	23.100	30.200	–	–
4	8	5.0	4.5	16.0	0.450	5.500	26.500	32.450	–	–
5	8	5.3	4.0	16.5	0.500	5.800	20.100	26.400	–	–
6	8	5.0	4.0	16.5	0.490	5.500	25.800	31.790	–	–
7	8	5.0	4.0	16.0	0.500	6.000	26.100	32.600	–	–
8	8	5.4	4.5	16.5	0.590	5.500	27.200	33.290	–	–
9	8	5.0	4.1	16.0	0.550	5.700	26.500	32.750	2.100	34.800
10	8	5.0	4.0	16.5	0.500	6.000	24.700	31.200	–	–
11	8	5.0	4.2	16.4	0.550	5.500	23.500	29.550	–	–
12	8	5.3	4.5	16.0	0.500	5.000	18.800	24.300	–	–
13	8	5.0	4.0	16.5	0.510	6.100	27.200	33.810	–	–
14	8	5.0	4.0	16.5	0.550	5.600	25.800	31.950	–	–
15	8	5.3	4.5	16.0	0.550	6.000	28.180	34.650	1.800	36.450

Different components of bamboo such as leaves, branches, culms and rhizome were collected individualy from 8-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2°C for dry weight determination.

Table 15. Organic matter distribution in 9th year *Bambusa Bambos*

Sample culm No.	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (cm)	Leaf	Branches	Culm	TAGB	Rhizomes	GTB
							kg/culm			
1	9	3.5	2.8	9.5	0.300	4.000	10.100	14.400	1.660	16.000
2	9	3.5	2.8	9.0	0.300	4.150	13.500	17.950	–	–
3	9	3.5	3.0	8.5	0.350	5.000	15.100	20.450	–	–
4	9	4.0	3.0	8.5	0.400	4.000	14.200	18.600	–	–
5	9	4.0	3.0	8.5	0.300	4.100	13.000	17.400	–	–
6	9	3.5	2.8	8.0	0.325	4.300	10.000	14.625	–	–
7	9	3.5	2.8	8.5	0.300	4.700	10.500	15.500	–	–
8	9	4.0	3.0	8.5	0.290	4.100	14.100	18.490	–	–
9	9	4.0	3.0	9.0	0.300	4.000	13.500	17.800	1.300	19.100
10	9	3.5	2.8	9.0	0.350	4.200	15.100	19.650	–	–
11	9	3.5	2.8	8.5	0.300	5.000	15.500	20.800	–	–
12	9	4.0	3.0	8.0	0.300	4.500	16.100	20.900	–	–
13	9	3.5	2.8	8.5	0.310	4.500	15.100	19.910	–	–
14	9	3.5	2.8	8.5	0.350	4.000	15.000	19.350	–	–
15	9	3.5	2.8	8.5	0.300	4.200	14.100	18.600	1.200	19.800

Different components of bamboo such as leaves, branches, culms and rhizome were collected individualy from 9-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2°C for dry weight determination.

Table 16. Organic matter distribution in 10th year *Bambusa bambos*

S.No.	Sample culm number	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (m)	BIOMASS (KG/CULM)					
						Leaf	Branches	Culms	Total above ground biomass (kg)	Rhizome (kg)	Grand total biomass (kg)
1	1	10	3.0	2.7	7.5	0.270	3.100	12.200	15.900	1.270	17.170
2	2	10	3.0	2.5	7.5	0.275	3.250	12.800	16.325	–	–
3	3	10	2.7	2.5	7.5	0.290	3.100	12.000	15.525	–	–
4	4	10	3.0	2.5	7.0	0.270	3.100	13.000	16.370	–	–
5	5	10	2.5	2.5	7.0	0.275	3.400	13.000	16.675	–	–
6	6	10	3.0	2.9	7.5	0.270	3.700	12.900	16.870	–	–
7	7	10	3.0	2.5	7.0	0.275	3.100	12.700	16.075	–	–
8	8	10	3.0	2.5	7.4	0.275	3.200	12.800	16.275	–	–
9	9	10	2.5	2.5	7.5	0.274	3.000	11.900	15.174	–	–
10	10	10	2.7	2.5	7.5	0.275	2.975	11.900	15.150	1.270	16.420
11	11	10	3.0	2.5	7.0	0.270	3.000	11.800	15.070	–	–
12	12	10	3.0	2.5	7.0	0.275	3.000	12.800	16.075	–	–
13	13	10	3.0	2.7	7.5	0.270	3.000	11.900	15.170	–	–
14	14	10	3.0	2.7	7.0	0.270	2.975	12.100	15.345	–	–
15	15	10	3.0	2.5	7.5	0.275	3.100	13.000	16.375	1.270	17.645

Different components of bamboo such as leaves, branches, culms and rhizome were collected individualy from 10-year old stand and their fresh weight was taken in the field. They were dried in the laboratory at 103 ± 2°C for dry weight determination.

The culms of plants had higher biomass with respect to dry weight. The culm biomass would be increased by 5.1 times from the 1st year (0.588 kg/culm) to the 2nd year (3.020 kg/culm), by 15.6 times in the 3rd year (9.750 kg/culm); by 45 times in the 4th year (26.500 kg/culm), by 79.6 times in the 5th year (46.800 kg/culm) and by 97.1 times in the 6th year (57.113 kg/culm) and may be decreased to 61.2 times in the 7th year (35.786 kg/culm) by 42.5 times to 8th year (25.026 kg/culm) and 23.5 times to 10th year.

The branch biomass dry weight would be increased by 2.1 times from the 1st year (0.394 kg/culm) to the 2nd year (0.843 kg/culm); by 14.4 times in the 3rd year (5.705 kg/culm); by 19.6 times in the 4th year (7.760 kg/culm); by 21.5 times in the 5th year (8.485 kg/culm) and by 23.8 times in the 6th year (9.385 kg/culm) and may be decreased to 16.4 times to 7th year (6.493 kg/culm), by 14.4 times to 8th year (5.693 kg/culm) and 10.9 times to 10th year (4.310 kg/culm).

With regard to leaf, it would increased by 2.2 times from the 1st year (0.133 kg/culm) to the 2nd year (0.297 kg/culm); by 2.8 times in the 3rd year (0.374 kg/culm); by 4.0 times in the 4th year (0.532 kg/culm); by 6.6 times in the 5th year (0.886 kg/culm) and by 7.1 times in the 6th year (0.946 kg/culm) and may be decreased by 4.3 times in 7th year (0.584 kg/culm), by 3.7 times in 8th year (F 0.562 kg/culm) and by 2.3 times in 10th year (0.318 kg/culm).

The total biomass of the above ground (culm, branch and leaf) may calculated, the weight could increase concomitant with age and individual parts. Total above ground biomass would increased from 1.085 to 67.444 kg/culm. The dry weight increase may be 3.8 times from the 1st year (1.085 kg/culm) to the 2nd year (4.160 kg/culm), by 14.5 in the 3rd year (15.829 kg/culm); 32.0 times in the 4th year (34.790 kg/culm); by 51.7 times in the 5th year (56.171 kg/culm) to 62.1 times in the 6th year (67.444 kg/culm) and may decreased by 39.6 times in 7th year, 28.7 times in 8th year, and 17 times in 10th year.

The rhizome biomass of sample culm which may found below ground, would also increased with age. At the end of the 1st year the dry weight may be 0.750 kg/culm which increased to 1.8 times in the 2nd year (1.400 kg/culm); by 2.1 times in the 3rd year (1.600 kg/culm); by 2.3 times in the 4th year (1.730 kg/culm); to 3.2 times in the 5th year (2.400 kg/culm) and by 3.5 times in the 6th year (2.640 kg/culm) and may be decreased by 3.3 times in 7th year (2.537 kg/culm) by 2.6 times in 8th year (1.760 kg/culm) and by 1.8 times in 10th year (1.360 kg/culm).

The grand total biomass of both below and above ground crop mean average of trees (culm) would increased by 3.0 times from the

1st year (1.835 kg/culm) to the 2nd year (5.560 kg/culm); by 9.5 times in the to 3rd year (17.489 kg/culm); by 19.9 times in the 4th year (36.522 kg/culm); by 31.9 times in the 5th year (58.571 kg/culm) and by 38.1 times in the 6th year (70.084 kg/culm) and may be decreased by 24.8 times in 7th year (45.600 kg/culm) by 18 times in 8th year (33.181 kg/culm) and by 10.8 times in 10th year (Table 17).

With regard to contribution of different plant components to total shoot weight (total above ground biomass) the culm would contributes maximum in all age groups. It may gradually increased from 30 per cent in the 1st year, 55 per cent in the 2nd year, 56 per cent in the 3rd year, 73 per cent in the 4th year; 80 per cent in the 5th year; and 85 per cent in the 6th year. After 6th year, the contribution of culm may be decreased to 79%, 75% and 72% in 7,8,9 and 10th years.

The percentage contribution of branches to total shoot, showed considerable variation among the ages. The contribution of branch may be 22 per cent in the 1st year, which declined to 15 per cent in the 2nd year; but would tended to increase to 33 per cent in the 3rd year, further may be decreased to 20 per cent in the 4th year, and 14 per cent in the 5th and 6th years. Then the contribution of branch biomass would decreased to 15%, 17% and 18% in 7, 8, and 9th years. The contribution of leaves to total shoot weight would gradually decreased to 7 per cent in the 1st year, 5 per cent in the 2nd year, 2 per cent would in 3rd, 4th and 5th year and would be only 1 per cent during 6th year, 7th and 9th year. It would suggest that more of the dry matter may be partitioned in non-photosynthetic tissue, especially in culm.

The percent contribution of total above ground biomass and rhizome to the grand total biomass could showed considerable variation in different ages. The contribution of total above ground biomass to grand total biomass on mean average of tree (culm) basis, would be increased to 59 per cent, 75 per cent, 91 per cent, 91 per cent in the 1st, 2nd, 3rd 4th, 7th 8th years respectively and 96 per cent in the 5th, 6th and 9th years. It may be apparent that the rhizome biomass to grand total biomass declined to 41, 25, 9, 5 per cent in the 1st, 2nd, 3rd, 4th and 10th years respectively. It may be evident that, maximum accumulation of biomass would takes place in the above ground system in bamboos (Table 18).

The total biomass considered in relation to age and DBH, the increase may be proportional in both diameter of the culm and the dry weight. The DBH would increased from 2.3 cm to 8.3 cm in six years, concomitant with expansion in diameter of the culm, the total weight would also increased to 242.73 t/ha in the sixth year (Table 19).

Table 17. Average biomass of sample *Bambusa bambos*

Age (years)	Leaf biomass		Branch biomass		Culm biomass		Total above ground biomass		Rhizome biomass		Grand Total Biomass	
	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)
1	0.332	0.133	0.980	0.394	1.470	0.588	2.782	1.085	1.250	0.750	4.032	1.835
2	0.655	0.297	1.837	0.843	6.711	3.020	9.239	4.160	2.333	1.400	11.572	5.560
3	0.831	0.374	12.677	5.705	21.666	9.750	35.174	15.829	3.018	1.660	38.142	17.489
4	1.064	0.532	15.520	7.760	53.000	26.500	69.584	34.790	3.460	1.730	73.044	36.522
5	1.775	0.886	16.970	8.485	93.600	46.800	112.345	56.171	4.800	2.400	117.145	58.571
6	1.895	0.946	18.430	9.385	114.840	57.113	135.160	67.444	5.280	2.640	140.168	70.084
7	1.260	0.584	13.100	6.493	69.400	35.986	83.760	43.073	4.700	2.537	88.460	45.600
8	1.110	0.502	12.550	5.693	45.200	25.026	58.860	31.221	3.850	1.960	62.710	33.180
9	0.980	0.318	10.810	4.310	30.800	13.860	42.590	18.488	2.500	1.360	45.090	19.848
10	0.810	0.273	9.100	3.170	27.300	12.700	37.210	16.143	2.100	1.270	39.310	17.413

Different components of bamboo such as culm, branch, leaves and rhizome were collected individually, their fresh wieght was taken in the field. They were dried in the laboratory for dry weight determination. The values are expressed as average of three independent experiments.

Table 18. Percentage of individual culm components of *Bambusa bambos*

Age (years)	Average diameter (cm)	Average height (m)	Leaf biomass (%)	Branch biomass (%)	Culm biomass (%)	Rhizome biomass (%)
1	2.3	1.4	7.0	21	32	40.0
2	3.3	3.2	5.0	15	55	25.0
3	4.3	9.6	2.0	33	56	9.0
4	4.8	21.8	2.0	20	73	5.0
5	6.3	27.2	2.0	14	80	4.0
6	8.3	28.5	1.0	14	85	4.0
7	5.4	20.5	1.0	15	79	5.0
8	4.1	16.0	3.0	17	75	5.0
9	3.6	8.50	1.0	21	72	6.0
10	2.5	7.40	1.0	21	72	6.0

The percentage contribution of individual culm components were calculated. The culm contributes the maximum biomass followed by branch, rhizome and leaves.

Table 19. Production of biomass of *Bambusa bambos* on unit area basis (tonnes/ha)

Age (years)	Culm diameter (cm)	Culm height (m)	Basal area (cm)	Number of culms	Number of nodes	Leaf	Biomass t/ha Branches	Culm	Total above ground biomass	Rhizome biomass	Grand Total biomass
1	2.3	1.4	3.1	1250	7	0.166	0.493	0.698	1.356	0.938	2.294
2	3.3	3.2	4.0	2250	16	0.668	1.897	6.795	9.360	3.150	12.510
3	4.3	9.6	5.0	3000	37	1.122	17.115	29.250	47.487	4.980	52.467
4	4.8	21.8	6.1	3500	86	1.862	27.160	92.750	121.772	6.055	127.827
5	6.3	27.2	8.3	4000	98	3.544	33.940	187.224	224.708	9.600	234.308
6	8.3	28.5	10.1	4250	103	4.021	39.886	242.730	286.637	11.220	297.857
7	5.4	20.5	6.0	3250	81	1.898	21.102	116.954	139.954	8.245	148.199
8	4.1	16.0	5.4	2750	66	1.380	15.655	68.821	85.856	5.390	91.246
9	3.6	8.50	3.6	1500	44	0.477	6.455	20.790	27.732	2.040	29.772
10	2.5	7.40	3.0	900	37	0.246	2.853	11.430	14.529	1.143	15.672

The culm, branches, leaves and rhizome were collected individually, and after determining their fresh weight at the field, were oven dried at 103 ± 2°C in the laboratory. Their moisture free dry weight was determined. The average biomass values of the sample trees were multiplied with the number of culms in hectare, to calculate the unit area biomass. The values expressed are average of three independent experiments.

Proportional to the culms their associate such as branches and leaves would also adding biomass every year which may occupied a minimum percentage of the total biomass and would increasing from 0.166 t/ha in the 1st year to 4.021 t/ha in the sixth year which would be 24.2 times higher. The analogous branch biomass may be 0.493 t/ha in the 1st year and 39.886 t/ha in the 6th year which would be 80.9 time manifold.

The total biomass of culm, branch and leaves when analyzed for their total productivity, it may obviously seen from 1.356 t/ha to 286.637 t/ha. Though the above ground biomass would be high as much as 211.3 times, the below ground biomass may be not as expected. The rhizome dry weight would elevated from 0.938 t/ha to 11.22 t/ha in the 1st and 6th year respectively which would be 11.0 times higher. This figure when compared with above ground biomass will be 26 times smaller.

The total above ground biomass would increase 6.9 times from the 1st year (1.356 t/ha) to the 2nd year (99.360 t/ha); by 35.0 times to the 3rd year (47.487 t/ha); by 89.8 times to the 4th year (121.772 t/ha); by 165.7 times to the 5th year (224.708 t/ha); by 211.3 times to the 6th year (286.637 t/ha).

Rhizome may be an important below ground biomass for bamboo. It would be the seat of proliferation of culms. The tender the young rhizome of the bamboo may be flat from which sprouts culm (Plate 6). It would be noticed that, the rhizome biomass (t/ha) may increased by 3.3 times from the 1st year (0.938 t/ha) to the 2nd year (3.150 t/ha); by 5.3 times in the 3rd year (4.980 t/ha); by 6.4 times in the 4th year (6.055 t/ha); by 10.2 times in the 5th year (9.600 t/ha); and by 11.9 times in the 6th year (11.220 t/ha).

When all the bamboo biomass components need be totalled for the net production, the grand total biomass (t/ha) would increased by 5.4 times from the 1st year (2.294) to the 2nd year (12.510 t/ha); by 22.8 times to the 3rd year (52.467 t/ha); by 55.7 times to the 4th year (127.827 t/ha); by 102.8 times to the 5th year (234.308 t/ha); and by 129.8 times to the 6th year 297.857 t/ha) (Table 19).

The mean annual biomass accumulation would increased with stand age. But the data on mean periodic increment and net primary production would showed that the rate of biomass accumulation may be highest at the age of fifth year, during which a peak of 124.08 t/ha/yr in net primary production may be obtained (Table 20).

Generally the total above ground biomass (dry matter) may be increased concomitant with DBH and height of the culm. The culm which may contribute a major share to the total biomass. Ageing may

improves above ground biomass accumulation. Based on the available literature, we can't predict at what age the biomass accumulation may found to be higher. It may entirely depend upon the climatic, edaphic and silvicultural parameters of the plantations. However, maximum biomass accumulation in plantation bamboos noted at the age of six. In natural forest the culm dry weight of *Phyllostachys edulis, Phyllostachys reticulata* may varied between 44 and 13 kg respectively on their height and diameter to the age would also be lesser than their counterparts of plantation stands. The culm dry weight of *Dendrocalamus strictus, Bambusa bambos* and *Melocanna baccifera* appears to be more than *Phyllostachys* species, but with same diameter. The reason may be the culm height of the former three species appears to be taller, their dry weight with the same diameter. All the three species found to possess thick walls in their culms, which may tend to add more accumulation of biomass than *Phyllostachys* species (Ueda 1960). Taking into comparision with above three species in the natural forests the bamboo under plantations would showed 19 to 85 per cent heavier culm weight.

Table 20. Mean biomass production, net periodic increment and net primary production (t/ha/yr)

Age years	1	2	3	4	5	6
Mean annual production	2.29	6.25	17.48	31.95	48.86	49.64
Mean periodic annual production	2.29	10.22	39.95	75.36	106.48	63.55
Litter fall	N.D.	N.D.	N.D.	15.40	17.60	20.30
Net primary production	N.D.	N.D.	N.D.	90.76	124.08	83.85

Mean biomass production, net periodic increment and net primary production were calculated from the productivity data. The data on mean periodic increment and net primary production showed that the rate of biomass accumulation was highest at the age of fifth year, during which a peak of 124.08 t/ha/yr in the net primary production was obtained. (N.D. = Not determined)

With regard to the percentage contribution of biomass components to the above ground biomass, the plantation age will be an important factor. The percentage contribution of leaf (7% F to 1%) decreased with increasing age. This perhaps reflect that leaf formation may seizes with age and growth. The leaves may be deciduous. When they would fall off from the base of culms and branches the new ones may replace without any additional number. No definite trend may observed in case of branch. They need be produced as the culm elongates in height and the total number of branches may appear to be fixed with the growth of the culm. The percentage contribution of rhizome to grand total biomass may correlates with leaf. Several plantation crops such as *Eucalyptus*

tereticornis (Singh and Sharma, 1976), *E. hybrid* (George, 1977), *E. globulus* (Negi *et al.*, 1984 and Tandon *et al.*, 1988), (Pandey *et al.*, 1989 and George and Varghese, 1990 would fall in line with bamboo in these regards.

Compared with biomass measurements the annual yield of air-dry bamboo per ha of 3-4 year old plantation would found to be 6-7 t for Bambusa vulgaris and 1.0 t for *Gigantochloa aspera* (Chinte, 1965). The above ground biomass of the plantation 85 per cent higher. The above ground biomass of *Gigantochloa scortechnii* from Malaysia may be 71.9 t/ha in natural stand and 36.36 t/ha in a 3 year old plantation (Othman, 1993). This found to be lower than 3 year old plantation stand (47.48 t/ha) of Kallipatty, India. Compared with other fast growing tree species, 8.6 t/ha in four year old *Eucalyptus globulus* (Cromer, 1976), 47 t/ha in five year old *Leucaena leucocephala* (Pandey *et al.*, 1989) and 87 t/ha in six year old *Pinus caribaea* (Madgwich *et al.*, 1977) the bamboo biomass estimates may found to be 7 to 30 per cent higher.

The below ground and above ground biomass ratio between 1 and 6 year old plantation may varies from 0.69 to 0.04. One year old younger plants may develop vast lateral roots from their below ground parts and would provide the much needed water and nutrients to the plants. In older plants the aerial parts need be more developed than the under ground parts. This ratio may vary with plant species and their age. In a 8 year old plantation of *Populas deltoides* the ratio may be 0.1 (Kaul *et al.*, 1983). The ratio may be 0.30 in *Tectona grandis* (Prasad, 1984) and 0.28 in *Terminalia tomentosa* and 15-20 year old plants of natural dry deciduous teak forest. The 5 year old *Eucalyptus camaldulensis* and 15 year old *E. camaldulensis* plantation would have a ratio of 0.43 and 1.12 respectively (Prasad *et al.* 1984). All plantation and forest species may tend towards a similar direction, since all the plants would ultimately depending of the underground biomass for water and mineral nutrients.

The net primary production and mean annual biomass accumulation may depend on stand age. In 5 year old plantation bamboo 124.08 t/ha/yr may be attained, which is 7 to 19 per cent higher than tropical and subtropical plantations (Das and Ramakrishnan, 1987; Forrest and Ovington, 1970; Landgreen, 1978; Madgwick *et al.*, 1977; Prasad *et al.*, 1984 and Kadeba, 1991).

The dry organic matter density of *Bambusa bambos* may be approximately within the range of 1 to 10 kg/m^3 above the range of 0.52 to 0.88 kg/m^3 in other bamboo species (Suzuki and Jacalne, 1986) and 0.54 to 0.55 kg/m^3 of *Gigantochloa scortechnii* (Othman, 1992).

Biochemical analysis of bamboo leaf

The entire biomass productivity may depends ultimately on the photosynthetic efficiency of the leaf. Therefore, leaf anatomy, estimation of photosynthetic pigments, total protein, carbohydrates and starch need be investigated (Shanmughavel, 1995). The leaf may revealed Kranz anatomy and its chlorophyll, carotenoides, protein, carbohydrates and starch may inversely proportional with age (Table 21).

The significance of chlorophyll content in characterizing the productive potential of various crops has been repeatedly stressed (Suryanarayanan, 1978; Hegde and Bawachker, 1983; Tyagi and Malik 1988 and Malik *et al.*, 1993). The entire biomass productivity depends ultimately on the photosynthetic efficiency of the leaf. The bamboo leaf revealed Kranz anatomy which apparently proving a tropical grass and its total chlorophyll, carotenoides, proteins, carbohydrates and starch may inversely proportional with age. The results would have high correlation between the biomass productivity and chlorophyll content analogous to mango cultivars (Malik *et al.*, 1993). The total above ground biomass increased 6.9 times from 1 year to 2 year. Further increase would be in the order of 5.0, 2.5, 1.8, and 1.2 times from 2nd, 3rd, 4th and 5th year respectively. It may revealed that, the total above ground biomass increase would be decreased with the age of bamboo. It may be due to gradual decrease in all the biochemical constituents of bamboo leaf with increase in age. The biochemical constituents of Wild bamboo leaf 34 per cent higher than plantation crop. It reveals that under natural stand the constituents may be metabolized slowly resulting in lower turn over of biomass. However, the organic productivity of bamboos from plantation crop (Shanmughavel and Francis 1993) found higher than natural forest bamboo (Chinte 1965 and Othman 1992).

Biomass Prediction Equations

There has been a marked increase in the number of studies on forest biomass during the past decades with the realisation that total organic production is important instead of considering the forest a production system for stem wood. This is probably due to increasing pressure placed on our forests by the community such as demands for forest products, search for renewable source of raw materials etc. In addition to the productive role, the growing concern of well being of forest ecosystems has resulted in the appearance of numerous

Table 21. Biochemical characteristics of bamboo *(Bambusa bambos)* leaf

Age in years	Total Chlorophyll (μ/g)	Chlorophyll a (μ/g)	Chlorophyll b (μ/g)	Chlorophyll a,b ratio	Carotenoides (μ/g)	Protein (mg/g)	Carbohydrate (mg/g)	Starch (mg/g)
Wild	602	266	328	0.81	91.35	10.41	12.00	811.95
1	551	248	298	0.83	64.00	7.53	8.78	588.35
2	544	237	302	0.78	58.53	7.23	7.95	537.30
3	500	230	265	0.86	53.55	6.89	7.20	495.65
4	449	212	233	0.90	50.42	6.19	7.04	481.72
5	398	194	200	0.97	49.88	6.07	6.91	475.09
6	366	174	188	0.92	48.80	5.95	6.47	469.82
7	340	160	173	0.92	48.00	5.60	6.10	454.89
8	323	147	162	0.90	47.40	5.13	5.73	433.24
9	304	131	149	0.88	46.70	4.85	5.45	410.39
10	290	120	138	0.82	45.10	3.95	5.10	390.17

The values expressed are average of these independent experiments.

publications on forest biomass throughout the wold (Pande 1989), including India (Singh and Sharma 1976; George 1977, Negi, 1984, Shanmughavel 1995, Anbazhagan 1998). These studies are utilized by some researchers with a geographical stand point, relating the distribution of productivity over land surface to either climatic factor(s) the distribution of main plant community. Such studies give us a general idea of productivity over the earth, while negleting the productive relationship in any particular forest stand. On the other hand some researchers are concentrating on the pattern and process of production within a given forest stand as a base for understanding the energy flow and circulation of nutrients in the forest ecosystem (Satoo and Madgwick, 1982). This biomass studies are essential for estimating Net Primary Production (NPP), understanding nutrient cycling and energy transfer and predicting the effects of tree utilization, management procedures and stability of forest stand.

For biomass estimation two distinctly separate situations can be considered. On one hand there is a typical research situation in which samples of trees and subordinate vegetation can be weighed in field. While on the other hand the stand biomass can be estimated by prediction equations based on sampling over a wide geographical area.

Bamboo species are being extensively raised to meet the raising demands of bamboo based products. Biomass studies may be interest to the grower to judge the performance of species in terms of total biological production and to assess the nutrients drain by way of harvesting the species. In order to obviate the difficulty of felling standing green trees on the new site where the biomass estimation may be required, regression equations should be needed (George, 1977, Negi, 1986, and Shanmughavel 1995). Such regression equations should be worked out on the basis of easily measurable parameter utilizing the actual biomass data of *Bambusa bambos* plantations.

(i) Regression equations with single independent variable

Linearized curvilinear model : (Whittaker and Woodwell. 1968).

$\log (y) = a + b \log (x1)$

$\log (y) = a + b \log (x2)$

$\log (y) = a + b \log (x3)$

$\log (y) = a + b \log (x4)$

$\log (y) = a + b \log (x5)$

$\log (y) = a + b \log (x6)$

(ii) Regression equation with two independent variables

$\log y = a + b1\ x1 + b2 \log x2$

where y = biomass (kg), x1 = diameter (D) : x2 = H

x3 = D2H, X4 = BAH; x5 = D2; X6 = BA

a, bv = are usual constants and log is to the base e.

(iii) Multiple regression equation

$\log y = a + b1 \log x1 + b2 \log x2 + b3 \log x3 + b4 \log x4$

$+ b5 \log x5 + b6 \log x6.$

where y = biomass (kg), x1 diameter, x2 height

x3 = d, x4 = DH, x5 BA, x6 BAH.

Simple correlation coefficients between pairs of the variables total yield diameter (D) and height (H), diameter an height (DH), square of diameter and height (D^2H), square of diameter (D^2), basal area (BA), basal area and diameter (BAH) should be calculated (Table 22-29).

Table 22. Regression equations between diameter and dry weight of bamboo component (Y) for *Bambusa bambos*

	Component	Regression equation	Determination co- efficient (R^2)
1	Leaf	log y = -1.3238 + 1.4917 log D	0.9257
2	Branches	log y = -1.1330 + 2.5635 log D	0.8362
3	Culms	log y = -1.2471 + 3.5238 log D	0.9380
4	Total above ground biomass	log y = -0.8838 + 3.1908 log D	0.9353
5	Rhizome	log y = -0.2469 + 0.7075 log D	0.5540
6	Ground total biomass	log y = -0.5013 + 2.6021 log D	0.7745

A regression model was fitted between the oven dry weights of tree components as dependent variable and diameter as independent variable the model is

Log Y = a+b Log D

Where Y is oven dry weight of tree components. D is the diameter (DBH) in centimeter.

Table 23. Regression equations between D^2H and dry weight of bamboo component (Y) for *Bambusa bambos*

	Component	Regression equation	Determination co-efficient (R^2)
1	Leaf	log y = -1.1210 + 0.3330 log D^2H	0.9227
2	Branches	log y = -0.8495 + 0.6003 log D^2H	0.9190
3	Culms	log y = -0.8115 + 0.8057 log D^2H	0.9811
4	Total above ground biomass	log y = -0.4943 + 0.7318 log D^2H	0.9842
5	Rhizome	log y = -0.1896 + 0.1753 log D^2H	0.6730
6	Ground total biomass	log y = -0.1846 + 0.5982 log D^2H	0.8307

A regression model was fitted between the oven dry weights of tree components as dependent variable and square of diameter and height (D^2H) as independent variable; the model is Log Y = a+b Log D^2H
Where Y is oven dry weight of tree components, D is the diameter (DBH) in centimeter. H is the height in metres.

Table 24. Regression equations between BAH and dry weight of bamboo component (Y) for *Bambusa bambos*

	Component	Regression equation	Determination co-efficient (R^2)
1	Leaf	log y = -1.1303 + 0.4409 log BAH	0.9159
2	Branches	log y = -0.8759 + 0.7990 log BAH	0.9519
3	Culms	log y = -0.8439 + 1.0705 log BAH	0.9845
4	Total above ground biomass	log y = -0.5240 + 0.9724 log BAH	0.9879
5	Rhizome	log y = -0.1966 + 0.2339 log BAH	0.6952
6	Ground total biomass	log y = -0.1796 + 0.7818 log BAH	0.8231

A regression model was fitted between the oven dry weights of tree components as dependent variable and basal area and height (BAH) as independent variable; the model is Log Y = a + b Log BAH.
Where Y is oven dry weight of tree components - BA - Basal area in centimeter.
H is the height in metres.

Table 25. Regression equations between height and dry weight of bamboo component (Y) for *Bambusa bambos*

	Component	Regression equation	Determination co- efficient (R^2)
1	Leaf	log y = -0.9378 + 0.5805 log H	0.8891
2	Branches	log y = -0.5557 + 1.0828 log H	0.9494
3	Culms	log y = -0.3941 + 1.4310 log H	0.9811
4	Total above ground biomass	log y = -0.1175 + 1.3020 log H	0.9878
5	Rhizome	log y = -0.1149 + 0.3288 log H	0.7471
6	Ground total biomass	log y = -0.1296 + 1.0618 log H	0.8260

A regression model was fitted between the oven dry weights of tree components as dependent variable and height (H) as independent variable; the model is Log Y = a + b Log H
Where Y is oven dry weight of tree components, H is the height in metres.

Table 26. Regression equations between DH and dry weight of bamboo component (Y) for *Bambusa bambos*

	Component	Regression equation	Determination co-efficient (R^2)
1	Leaf	log y = -1.2293 + 1.0850 log D + 0.1691 log H	0.9324
2	Branches	log y = -0.4210 - 0.5014 log D + 1.2739 log H	0.9523
3	Culms	log y = -0.6464 + 0.9394 log D + 1.0748 log H	0.9870
4	Total above ground biomass	log y = -0.3003 + 0.6804 log D + 1.0440 log H	0.9915
5	Rhizome	log y = -0.1109 - 0.8413 log D + 0.6500 log H	0.8180
6	Ground total biomass	log y = -0.0836 + 0.7943 log D + 0.7586 log H	0.8327

A regression model was fitted between the oven dry weights of tree components as dependent variable. Diameter and Height (DH) as independent variable; the model is Log Y = a + b log DH.
Where Y is oven dry weight of tree components, D is diameter in centimeter is the height in metres.

Table 27. Regression equations between D^2 and dry weight of bamboo component (Y) for *Bambusa bambos*

	Component	Regression equation	Determination co-efficient (R^2)
1	Leaf	log y = -1.3244 + 0.7460 log D^2	0.9255
2	Branches	log y = -1.1337 + 1.2809 log D^2	0.8359
3	Culms	log y = -1.2482 + 1.7621 log D^2	0.9376
4	Total above ground biomass	log y = -0.8848 + 1.5956 log D^2	0.9349
5	Rhizome	log y = -0.2471 + 0.3537 log D^2	0.7439
6	Ground total biomass	log y = -0.5024 + 1.3013 log D^2	0.7941

A regression model was fitted between the oven dry weights of tree components as dependent variable, square of diameter (D^2) as independent variable; the model is Log Y = a + b Log D^2
Where Y is oven dry weight of tree components. D is diameter in centimeter.

Table 28. Regression equations between BA and dry weight of bamboo component (Y) for *Bambusa bambos*

	Component	Regression equation	Determination coefficient (R^2)
1	Leaf	log y = -1.5805 + 1.7460 log BA	0.8690
2	Branches	log y = -1.5158 + 2.6986 log BA	0.7667
3	Culms	log y = -1.8290 + 3.7823 log BA	0.8926
4	Total above ground biomass	log y = -1.4058 + 3.4183 log BA	0.8866
5	Rhizome	log y = -0.1966 + 0.2339 log BA	0.6952
6	Ground total biomass	log y = -0.7937 + 2.6398 log BA	0.7415

A regression model was fitted between the oven dry weights of tree components as dependent variable, Basal area (BA) as independent variable; the model is Log Y = a + b Log BA.
Where Y is oven dry weight of tree components, BA is diameter in centimeter.

Table 29. Multiple regression equation of diameter (X_2), height (X_2), square of diameter (X_3), square of diameter x height (X_4), basal area (X_5), basal area x height (X_6) with biomass component (Y)

Tree component	Multiple regression equation	Determination coefficient (R^2)
Leaf	log Y = 1.25+2.25 log X1 + 0.01 log X2 - 10.75 log X3 - 0.03 log X4 - 0.05 log X5 + 0.19 log X6	0.93
Branch	log Y = -0.45+10.40 log X1 + 0.14 log X2 + 4.21 log X3 + 0.71 log X4 - 0.23 log X5 + 0.38 log X6	0.95
Culm	log Y = -.077+63.90 log X1 + 0.09 log X2 - 32.92 log X3 + 0.22 log X4 - 0.10 log X5 + 0.70 log X6	0.99
Total avoe ground biomass	log Y = -0.40+40.90 log X1 + 0.09 log X2 - 20.6 log X3 + 0.29 log X4 - 0.11 log X5 + 0.61 log X6	0.99
Rhizome	log Y = 0.36+42.9 log X1 - 11.60 log X2 - 37.3 log X3 + 15.9 log X4 + 2.62 log X5 - 3.68 log X6	0.88
Grand total biomass	log Y = 0.33 + 105.2 log X1 - 4.99 log X2 - 60.4 log X3 + 9.34 log X4 + 1.35 log X5 - 3.68 log X5	0.85

* For 18 Bamboo's only
A regression model was fitted between the oven dry weight of tree components as dependent variable and diameter, height, square of diameter, square of diameter and height, basal area, basal area, and height as independent variable. The model is Log Y = a + b + b1 log X (D) + b2 log (H) + b3 log (D2) + b4 log (BA) + b6 log (BAH). Where Y is oven dry weight of tree components, D is diameter in centimeter, H is height in meter, D2 is square of diameter in centimeter, D2H is square of diameter and height in meter, BA is basal area in centimeter and BAH is basal area and height.

All the correlation coefficient (except for rhizome and Grant total biomass) found to be highly significant (at 0.01% level). On the basis of the value of determination of coefficient, the following regression equation may be found to be the best.

log Y = a + b log X1 (D) + b log X2 (H) (Table 26).

As far as the leaf, branch, culm, total above ground biomass concerned, the character DH accounts for 93 to 99 per cent variation. Whereas it comparatively lower in other components (rhizome and Grand total biomass). This may be mainly due to the lesser number of samples (18 bamboos may be evaluated for estimation of rhizome biomass and grand total biomass). Hence comparatively lesser variation may be explained in case of rhizome and grand total biomass.

The variable height and diameter should be used to predict bamboo biomass with reliable precision. Ogawa *et al.*, (1961) and Telfer (1969) found diameter at ground level to be closely related to leaf and total biomass. Height alone could be used to predict biomass of shrubs (Brown, 1976). The square of diameter and height related with total biomass (Madwich, 1971; Whittakar and Woodwell, 1968, Rai, 1984; Negi and Sharma, 1987, and Othman, 1992). Several regression equations have been developed to predict the biomass of shrubs and trees (Ohmann *et al.*, 1976; Brown, 1976, Crow, 1977; Stanek and State, 1978; Roussopolous and Loomis, 1979, Youdi *et al.*, 1985; Smith and Brand, 1983; Alaback, 1986 and Thakur *et al.*, 1993). Correlation coefficient (except rhizome and grand total biomass) may be highly significant (at 0.01% level). On the basis of the value of determination of coefficients, the following regression equation may found to be most suitable.

$$\text{Log } Y = a + b1, \log X1\ (D) + b2 \log X2\ (H)$$

Among the leaf, branch, culm and total above ground biomass, diameter and height may accounts for 93 to 99 per cent variation. Whereas, it may be comparatively lower in other components (rhizome and grand total biomass). This may because of the lesser number of samples (18 bamboos) evaluated for estimation of rhizome and grand total biomass.

There may be imperative need to utilising regression equations in productivity and biomass studies when there should be realistic estimates are to be derived. The application of regression equation may be comparatively much simple may requires the measurement of D.B.H. of trees and their height with altimeter. From the average D.B.H. and height, the biomass figures need be derived substituting the logarithmic values of the regression equation and should be multiplied with the number of trees per hectare.

CHAPTER - 8

NUTRIENT COMPOSITION IN GROWING BAMBOO

For proper understanding and management of the forest ecosystem, particularly the man-made forests, the total biological approach necessitates the knowledge of nutrient status of the forest ecosystems. Substantial information is available on nutrient in temperate, tropical and sub-tropical ecosystems of the world and in India, but comparatively no data is available about the nutrient change during the growth of bamboo. Being an extremely fast growing species, bamboo can be expected to consume large quantities of nutrients. The supply of nutrients considerably increases growth and biomass production (Anonymous 1961; Adamson *et al.*, 1978; Khader and Hussain 1980; Rao *et al.*, 1989; Patil, 1980; Uchimura, 1980; Kinhal 1985; Huang 1987, and Shi *et al.*, 1987). This chapter deals with the nutrient composition in growing bamboo.

NUTRIENT COMPOSITION

In plantation bamboo, the peak concentration of all nutrients (N, P, K, Ca and Mg) was the bud stage which decline during organ expansion stages. All nutrients were concentrated maximum in the actively growing regions (Mason and Whitefield, 1960, Rodin and Bazilvich, 1968). A steady decline in N, P, K, Ca and Mg levels, during the growth phases is in accordance with *Eucalyptus hybrid* (Singh, 1987, 1984) and in *Quercus leucotrichophora* (Lata and Bisht, 1993).

Primary productivity in ecosystem are influenced by several factors such as the availability of nutrients and water. Plants absorb nutrients and transport them to various growing regions for the production of organic compounds and their incorporation into biomass (Kramer and Kozlowski, 1960). Average rates at nutrient accumulation increased rapidly in the early stages of stand development but changes in nutrient content were less marked as the stand age increased (Kadeba, 1991). Higher N content in the leaves of bamboo is similar to Loblolly pine at the early stage of the stands (Aluko, 1993).

The changes in the nutrient composition during the growth of bamboo is presented in Table 30.

Table 30. Nutrient contents in the biomass of *Bambusa bambos*

S.No.	Sample days	N%	P%	K%	Ca%	Mg%
1	2nd day	2.85	0.63	2.45	1.50	1.69
2	10th day	2.80	0.54	2.20	1.41	1.65
3	20th day	2.70	0.48	2.10	1.34	1.55
4	32nd day	2.60	0.41	2.00	1.29	1.45
5	52nd day	2.54	0.38	1.80	1.20	1.38
6	64th day	2.50	0.37	1.78	1.13	1.30
7	75th day					
	Branch	1.69	0.30	1.44	0.79	0.90
	Culm	1.29	0.35	1.32	0.70	0.83
8	96th day					
	Branch	1.61	0.33	1.38	0.76	0.83
	Culm	1.25	0.31	1.25	0.74	0.79
9.	105th day					
	Leaf	1.90	0.33	1.60	0.96	1.05
	Branch	1.55	0.31	1.34	0.74	0.79
	Culm	1.21	0.29	1.20	0.72	0.74
10.	120th day					
	Leaf	1.80	0.31	1.53	0.89	1.00
	Branch	1.40	0.28	1.32	0.71	0.76
	Culm	1.40	0.21	1.18	0.68	0.70
11.	135th day					
	Leaf	1.60	0.28	1.50	0.79	0.99
	Branch	1.25	0.24	1.29	0.70	0.73
	Culm	1.10	0.21	1.18	0.68	0.70
12.	150th day					
	Leaf	1.57	0.24	1.41	0.73	0.88
	Branch	1.20	0.20	1.24	0.64	0.69

	Culm	0.99	0.15	1.10	0.57	0.60
13.	165th day					
	Leaf	1.30	0.20	1.26	0.60	0.68
	Branch	0.99	0.17	1.19	0.53	0.62
	Culm	0.87	0.13	1.00	0.51	0.58
14	180th day					
	Leaf	1.10	0.15	1.10	0.57	0.60
	Branch	0.85	0.10	1.15	0.50	0.57
	Culm	0.80	0.09	0.94	0.48	0.51
15	195th day					
	Leaf	1.05	0.10	1.00	0.51	0.54
	Branch	0.89	0.09	1.00	0.43	0.48
	Culm	0.82	0.08	0.89	0.41	0.46
16	210th day					
	Leaf	1.05	0.10	1.00	0.51	0.54
	Branch	0.89	0.09	1.00	0.430	0.48
	Culm	0.82	0.08	0.89	0.41	0.46

The different biomass components were collected from 2nd day onwards. Nitrogen and Phosphorus were estimated by using auto analyser (Technicon Auto Analyser-II-Gedko International Ltd., UK) Potassium, Calcium and Magnesium were estimated by using an atomic absorption spectrophotometer (Perkin Eimer 5000 USA). The results are the average of the three independent experiments.

Nitrogen content in the just sprouted (2nd day) bamboo was found to be 2.85 per cent. This nutrient gradually declined to 2.60 per cent on 32nd day and to 2.5 per cent on 64th day. On 52nd day branch buds appeared. In the branch bud N was 1.69 per cent, in culm in further decline to 1.29% on 7th day. On 105th day leaf bud appeared. The N content in leaf, branch and culm amounted to 1.90 per cent, 1.55 per cent and 1.21 per cent respectively. The nitrogen content further declined in all biomass components during 135th day, 156th day and 195th day. Thereafter, it remained constant.

Initial value of phosphorus at sprouting stage amounted 0.63 per cent. It decreased to 0.41 per cent on 32nd day, 0.37 per cent on 64th day. In branch bud, P was 0.30 per cent, in culm it further declines to 0.35 percent. The P content in leaf, branch and culm found to be 0.33 per cent, 0.31 and 0.28 respectively. After 6 month, no fluctuating trend in P content was noticed.

At the time of sprouting, potassium content amounted to 2.45 per cent. Declining trend was observed like other nutrients and found to be 2.00 per cent on 32nd day, 1.78 per cent on 64th day. In branch bud and leaf bud, K amounted 1.44 per cent and 1.60 per cent respectively. It further declined, during the growth then it reached a constant value.

Higher concentration of calcium was found at sprouting stage 1.50 per cent. It declined to 1.29 per cent on 32nd day, 1.13 per cent on 64th day. The initial value of Ca during branch bud at 75th day and leaf bud during 105th day amounted as 0.79 per cent and 0.96 respectively. It further declines and remain constant after 200 days. The final value of Ca at maturity in leaf, branch and culm found as 0.51 per cent, 0.43 per cent and 0.41 respectively.

In Magnesium maximum 1.69 per cent of accumulation noticed during early sprouting stage which declined to 1.45 per cent on 32nd day, 1.30 per cent on 64th day. In branch bud and leaf bud the Mg per cent content noticed as 0.90 per cent 1.05 per cent respectively. Similar to other elements, Mg also found to decline upto 200 days. After this period, the Mg value in leaf, branch and culm found as 0.54 per cent, 0.48 per cent and 0.46 per cent respectively.

CHAPTER - 9

DYNAMICS OF NUTRIENTS IN BAMBOO

1. NUTRIENT CONTENT IN STANDING CROP

The importance of nutrient levels in biomass production system may be of paramount. Even in natural ecosystem the nutrient budgeting is delicately balanced. The importance of nutrient management may well recognised from early times, which should become highly relevant with advent of commercial forestry, where in there should be continuous increase in production and removal of biomass out of the system. Such impact of intensive harvesting need extensive investigation. Understanding of nutrient distribution in different components of plants in terms of cycling through the process such as geochemical, biochemical and biogiochemical mechanisms need to be investigated. The relative contribution of this process may generally be studied by examining the soil litter system which include the mineralization of organic product for growth, uptake of nutrients, distribution of nutrients in the plantation ecosystems. These studies may be of paramount important to suggest the nutrient budgeting of an ecosystem.

(a) Nutrient concentration

The concentration of different nutrients in various biomass components may be varied considerably in these plantation. Considering the amount of different nutrients in various biomass components, the highest concentration may generally observed in leaf, branch, culm and rhizome. The proportion of nutrient elements

in leaf may be in order of Nitrogen Potassium Magnesium Calcium Phosphorus, in branch Potassium Nitrogen Magnesium Calcium Phosphorus, in culm Potassium Nitrogen Magnesium Calcium Phosphorus and in rhizome Potassium Nitrogen Magnesium Calcium Phosphorus. (Table 31-34).

Table 31. Nutrient concentration in leaves

Nutrients mg g^{-1}	AGE (Years)									
	1	2	3	4	5	6	7	8	9	10
N	7.9	8.8	9.0	9.3	9.7	9.1	9.2	8.5	7.7	7.3
P	0.8	0.8	0.9	0.9	1.0	1.0	1.0	0.9	0.9	0.9
K	7.6	8.2	8.7	9.0	9.5	9.0	9.0	8.0	7.5	6.9
Ca	2.3	2.9	3.3	3.8	4.4	4.5	4.5	4.5	4.3	4.0
Mg	3.4	3.7	4.3	4.9	5.2	5.2	5.2	5.2	4.5	4.5

Table 32. Nutrient concentration in branches

Nutrients mg g^{-1}	AGE (Years)									
	1	2	3	4	5	6	7	8	9	10
N	6.5	6.7	7.0	7.9	8.3	8.3	8.5	8.0	7.6	7.0
P	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.8	0.8	0.8
K	6.7	7.3	7.8	8.4	8.9	10.0	9.5	8.8	8.4	7.9
Ca	2.0	2.3	2.9	3.1	3.8	4.3	4.0	3.5	3.3	3.0
Mg	3.0	3.2	3.8	4.0	4.6	4.8	4.5	4.0	3.8	3.5

Table 33. Nutrient concentration in culm

Nutrients mg g^{-1}	AGE (Years)									
	1	2	3	4	5	6	7	8	9	10
N	6.0	6.4	6.7	7.4	7.8	7.8	8.0	7.5	7.3	7.0
P	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.7	0.7	0.7
K	6.4	6.9	7.4	7.9	8.2	8.3	8.5	8.0	7.8	7.5
Ca	1.8	2.3	3.0	3.6	3.9	3.9	4.0	3.7	3.5	3.0
Mg	2.9	3.3	4.1	4.3	4.4	4.6	4.3	4.0	4.0	3.5

Table 34. Nutrient concentration in Rhizome

Nutrients mg g^{-1}	AGE (Years)									
	1	2	3	4	5	6	7	8	9	10
N	5.7	06.0	6.3	6.9	7.3	7.5	7.2	6.8	6.3	6.0
P	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.6	0.6
K	6.0	6.40	6.9	7.3	7.9	8.0	8.0	7.5	7.2	6.8
Ca	1.6	2.0	2.9	03.4	3.6	3.6	3.5	3.0	2.5	2.3
Mg	2.5	2.7	3.1	3.5	3.9	3.9	4.0	3.8	3.3	3.0

(b) Distribution of Nutrient elements

The distribution of elements in the leaf, branch, culm and rhizome need be studied. Leaf may contained 33-36 per cent of the

nitrogen, 3-4 per cent of the phosphorus, 31-35 per cent of the potassium, 10-16 per cent of the calcium and 15-17 per cent of the magnesium, whereas branch contained 31-37 per cent of the nitrogen, 3-4 per cent of the phosphorus, 35-37 per cent of the potassium, 10-15 per cent of the calcium and 11-18 per cent of the magnesium, the culm contained 30-34 per cent of the nitrogen, 3-4 per cent of the phosphorus, 33-36 per cent of the potassium, 10-16 per cent of the calcium and 17-19 per cent of the magnesium in aerial shoots. (Table 35).

Table 35. Distribution of Nutrients (% dry matter) of the above ground biomass of *Bambusa Bambos*

Years	Nutrients (% dry matter)	Leaves	Branch	Culm
1	N	36	37	34
	P	4	4	4
	K	35	37	34
	Ca	10	11	10
	Mg	15	11	16
2	N	37	34	33
	P	3	3	3
	K	35	37	35
	Ca	12	10	12
	Mg	13	16	17
3	N	34	32	30
	P	3	4	3
	K	33	36	34
	Ca	13	10	14
	Mg	17	18	19
4	N	34	33	31
	P	3	3	3
	K	33	35	33
	Ca	13	12	15
	Mg	17	17	18
5	N	33	31	31
	P	3	3	3
	K	32	34	33
	Ca	15	14	15
	Mg	17	18	18
6	N	33	31	31
	P	3	3	3
	K	31	35	33
	Ca	16	15	16
	Mg	17	16	17

(c) Nutrient retention

The average annual production and nutrient retention may be obtained by multiplying the productivity of biomass components with their respective nutrient concentration (Table 36A-E). It may be observed that on unit area basis (Kg/ha) the maximum amount of all nutrients may found in culm followed by branches, rhizome and leaves. Therefore maximum drain of all nutrients may occurs through culm harvest and among the nutrients maximum drain may be for potassium, followed by nitrogen, magnesium, calcium and phosphorus.

Table 36A. Nutrient retained in leaves of the average annual biomass production (Kg ha^{-1} $year^{-1}$)

Nutrients	AGE (Years)									
	1	2	3	4	5	6	7	8	9	10
N	1.31	5.87	11.0	18.0	34.5	42.0	17.46	11.73	3.67	1.79
P	0.13	0.53	1.0	2.0	4.0	4.0	1.89	1.24	0.42	0.22
K	1.26	5.47	9.76	17.0	34.0	40.0	17.00	11.00	3.57	1.69
Ca	0.38	1.93	3.70	7.0	16.0	21.0	9.49	6.21	2.05	0.98
Mg	0.56	2.47	4.82	9.0	18.0	22.0	9.86	7.17	2.14	1.10

Table 36B. Nutrient retained in branches of the average annual biomass production (Kg ha^{-1} $year^{-1}$)

Nutrients	AGE (Years)									
	1	2	3	4	5	6	7	8	9	10
N	3.89	16.66	54.04	215.00	282.00	355.00	179.36	125.24	49.05	19.97
P	0.39	01.51	75.40	22.00	27.00	36.00	18.99	12.52	5.16	2.28
K	3.74	15.55	148.90	228.00	302.00	399.00	200.46	137.76	50.99	22.53
Ca	1.13	5.50	56.47	79.00	129.00	172.00	84.40	54.79	21.30	8.55
Mg	1.67	7.01	73.59	109.00	156.00	191.00	94.95	62.62	24.52	9.98

Table 36C. Nutrient retained in culms of the average annual biomass production (Kg ha^{-1} $year^{-1}$)

Nutr-ients	AGE (Years)									
	1	2	3	4	5	6	7	8	9	10
N	4.18	43.48	195.90	686.00	1460.0	1990.0	935.63	516.15	151.76	80.01
P	0.41	4.07	20.47	65.00	150.00	194.00	93.56	48.17	14.55	8.00
K	4.46	46.88	216.45	733.00	1535.0	2160.0	994.07	550.56	162.16	85.72
Ca	1.25	15.62	87.75	334.00	730.00	995.00	467.00	254.63	72.76	34.29
Mg	2.02	22.42	119.25	399.00	824.00	1117.0	502.88	275.28	83.16	40.00

Table 36D. Nutrient retained in rhizome of the average annual biomass Production (Kg ha^{-1} $year^{-1}$)

Nutrients	AGE (Years)									
	1	2	3	4	5	6	7	8	9	10
N	5.34	18.90	31.34	43.00	70.00	86.00	60.84	36.65	12.85	8.58
P	0.46	1.57	2.98	4.00	7.00	8.00	5.76	3.77	1.22	0.68
K	5.62	20.16	34.36	44.00	76.00	94.00	65.92	40.42	14.68	7.75
Ca	1.50	5.04	14.44	21.00	35.00	44.00	28.84	16.17	5.10	02.62
Mg	2.34	7.87	15.43	21.00	37.00	48.00	32.96	20.48	26.73	43.42

Table 36E. Nutrient retained (kg/ha/yr) in the average annual production at the age of 4th year *Bambusa Bambos*

Components	Nutrients				
	N	P	K	Ca	Mg
Leaf	18.0	2.0	17.0	7.0	9.0
Branches	214.0	22.0	228.0	84.0	108.4
Culm	686.0	65.0	732.0	334.0	399.0
Total nutrients in above ground biomass	918.0	89.0	977.0	425.0	516.0
Rhizome	41.0	4.0	44.0	20.0	21.0
Grand Total	959.0	93.0	1021.0	445.0	537.0
Production at the Age of 5th year *Bambusa Bambos*					
Leaf	34.0	4.0	33.0	16.0	18.0
Branches	281.0	27.0	302.0	129.0	156.0
Culm	1460.0	150.0	1535.0	730.0	824.0
Total in above ground biomass	1775.0	181.0	1870.0	875.0	998.0
Grand Total	1845.0	188.0	1946.0	910.0	1035.0
Production at the age of 6th year *Bambusa Bambos*					
Leaf	42	4	40	21	22
Branches	355	36	399	172	191
Culm	1990	194	2160	995	1117
Total	2387	234	2599	1188	1330
Rhizome	86	8	94	44	48

Nutrients retained in the average annual production at the age of 4-6 year was obtained by multiplying in the productivity of biomass components with their respective nutrient concentration. The nutrient retained was found in the order of Potassium > Nitrogen > Magnesium > Calcium > Phosphorus.

2. BALANCE AND TURNOVER OF NUTRIENTS

The fractional turn-over of each element may be calculated by dividing the quantity which left a given ecosystem compartment by the quantity held in that compartment (Reiners and Reiners 1970). To compare the rates at which elements would be incorporated into the

vegetation, the enrichment ratio may be calculated for each element as the quotient of its increase in the above ground living biomass plus litter fall (Woodwell, *et al.*, 1975).

Little may be known previously about the role of bamboos in the cycling and conservation of nutrients in successional communities (Toky and Ramakrishnan, 1983). However, in plantation bamboo, the study has shown that the bambo may collectively accumulated more nutrient elements than in comparison with other studies (Greenland and Kowal 1960; Grubb and Edwards, 1982). It may be of interest that, though element storage in the biomass and recycling through litter may increased in age, element turn-over rates may also varied. Annual nutrient accumulation may improved with age and the enrichment ratio for all these elements may also showed improvement with age in *Dendrocalamus hamiltonii, Neohouzeau dulloa and Bambusa khasiana* (Rao and Ramakrishnan, 1989). Bamboo plays an important nutrient conservational role in plantation ecosystems. Bamboos follow a strategy of faster uptake and storage of essential elements but a slower turn-over to supplement the soil. Hence, necessary precautions need be observed, while exploiting large scale plantations of bamboo to maintain the fertility status of the soil (Table 37).

3. NUTRIENT COMPOSITION

The concentration of nutrients in the aerial shoots and rhizome may increased with age. The nutrient elements in leaf may be in the order N K Mg Ca P, while in branch, culm, rhizome it may be of K N Mg Ca P, in *Dendrocalamus hamiltonni* (Toky and Ramakrishnan, 1983) and *Bambusa balcooa, Dendrocalamus strictus, Thyrostachys olivery* (Tewari *et al.*, 1994) *Dendrocalamus hamiltonii, Bambusa tulda, Neohouzea dulloa*. In *Bambusa khasiana* it may be of K N Ca Mg P (Rao and Ramakrishnana, 1983).

Among the cations the concentration of potassium observed to be maximum. In this context, bamboo may plays an important role, in conservation of potassium because of its ability for rapid uptake and accumulation. Among the total accumulation of nutrients K alone may contributed to about 51 per cent. The weight of elements may increased linearly with biomass (Toky and Ramakrishnan, 1983). In bamboo plantation K, may be a predominant element over N, Ca, Mg and P and may analogous to slash and burn agriculture on plant nutrients in the territory region of central Amazonia (Brinkmann and Nascimento, 1973 and Suebert *et al.*, 1977), Costa Rican wet forest

site (Ewel *et al.* 1981) in South America, *Dendrocalamus strictus* (Toky and Ramakrishnan, 1983) in India. However, the total accumulation of potassium in *Bambusa bambos* may be 5 to 10 per cent higher.

Nitrogen in leaf may found proportionately higher. Higher allocation of N to the leaf component may be related to photosynthetic efficiency, since leaf N may positively related to photosynthetic rate (Murata, 1969; Terry and Ulrich 1973; Natr, 1975; Field, 1983 and Rao and Ramakrishnan, 1988). In *Dendrocalamus hamiltonii* (Toky and Ramakrishnan, 1982) K may replaced the leaf nitrogen followed by branches and culms. Calcium and magnesium annual uptake may higher in comparison with other fast growing species.

The per cent allocation of nutrients in different compartments of aerial parts of the bamboo stand may be calculated on a hectare basis and compared. There may be a close relation in per cent allocation of dry matter to different components of the bamboo which may related to the age of the stand. In a young stand of *Bambusa bambos* of 1 year old, 30% and 7% of dry matter may be allocated in the culm and in leaves respectively. Distribution of N, P, K, Ca and Mg may be between 4-34% in the culm and 4-36% in leaves may indicate more allocation of nutrient to the latter. In 6 year old stands dry matter and nutrients may be more towards the bole than the leaves.

With increase in stand age, shift in the nutrient allocation may be more towards in the bole which may reveals more dry matter production in the bole than others (Ovington, 1962 and Madgwick *et al.*, 1977).

4. NUTRIENTS RETAINED

The nutrient contents of the standing crop may differed substantially in various forest types according to the degree of uptake and crop biomass, which inturn may dependent on tree age and site quality (Ovington, 1962 and Roddin and Bazilevich, 1967). On unit area basis the maximum amount of all nutrients may found in culm followed by branches, rhizoms and leaves. Therefore, maximum drain of K may occurs followed by N, Mg, Ca and P, in *Dendrocalamus hamiltonii* (Toky and Ramakrishnan, 1983). In *Dendrocalamus hamiltonii, Bambusa tulda, Neohouzeua dulloa* and *Bambusa khasiana* the maximum retention may be in the order K N Ca Mg P (Rao and Ramakrishnan, 1989). Since the annual nutrient content should usually followed by biomass expansion (average annual production it may increased linearly during the period of rapid growth and may diminishes at maturity (Pritckett, 1979).

Table 37. Inventory of nutrient elements in plantation bamboo *(Bambusa bambos)*

Inventory	Age in Years					
	1	2	3	4	5	6
Above ground biomass ($1x10^{-3}$ kg.ha^{-1})	1.3	9.3	47.4	122.0	225.0	287.0
NITROGEN						
Release through litter (kg.ha-1)	2.3	36.0	73.0	150.0	170.0	196.0
% annual turn over	16.4	44.2	20.4	15.5	170.0	8.0
Annual nutrient accumulation (kg.ha-1)	8.6	62.3	326.0	919.0	9.2	2387.2
Enrichment ratio	5.0	7.0	8.0	8.1	23.2	34.0
PHOSPHORUS						
Release through litter (kg.ha-1)	0.14	2.2	5.3	10.0	14.0	16.0
% annual turn over	10.4	31.2	14.0	12.00	7.3	6.6
Annual nutrient accumulation (kg.ha-1)	0.8	0.5	35.0	88.0	180.5	234.0
Enrichment ratio	0.4	0.5	0.8	0.8	2.3	3.3
POTASSIUM						
Release through litter (kg.ha-1)	2.2	35.3	72.2	146.3	165.3	188.7
% annual turn over	15.0	52.0	18.3	14.3	8.4	7.0

Table 37 contd...

Table 37 contd...

Annual nutrient accumulation (kg.ha-1)	9.0	66.3	359.0	978.0	1870.0	2599.0
Enrichment ratio	5.30	5.0	9.4	8.4	24.4	35.3
CALCIUM						
Release through litter (kg.ha-1)	0.96	15.5	33.4	69.3	84.4	97.4
% annual turn over	23.3	56.2	23.3	15.0	9.0	8.0
Annual nutrient accumulation (kg.ha-1)	2.6	21.4	130.00	420.0	875.0	1188.0
Enrichment ratio	1.4	2.3	3.1	3.4	11.4	16.4
MAGNESIUM						
Release through litter (kg.ha-1)	1.0	17.1	35.0	73.0	88.0	103.5
% annual turn over	19.4	43.3	17.0	134.0	8:5	7.50
Annual nutrient accumulation (kg.ha-1)	3.5	30.40	189.0	517.0	9989.0	01330.0
Enrichment ratio	2.0	3.3	4.4	4.5	13.0	18.3

The nutrient retention in *Bambusa bambos* plantations are not within the values obtained in other plantations *Pinus radiata* (Madwick *et al.*, 1977), *P. banksiana* (Foster and Morrison, 1979), *P. kesiya* (Das and Ramakrishnan, 1987), *Eucalyptus hybrid* (Negi, 1984 and George, 1977), *E. saligna* (Wise and Pitman, 1981), *E. grandis* (Turner and Lambert, 1983), *E. divisicolor* (Hingston *et al.*, 1979).

CHAPTER - 10

NUTRIENT CYCLING

The interchange of chemical elements between living organisms and the physical and biological components of forest ecosystem may forms an extremely complicated system, essentially cyclic in nature and may broadly following the organic system (Ovington, 1962). In order to understand the magnitude and pattern of circulation of the chemical elements, which may characteristic of an individual element, the cycling rate and standing state will have to be quantified. Nutrient cycling may be a good indicator of the continuity and stability of any living system and may believed to be an useful strategy for ecosystem analysis (Pomeroy, 1970).

In a forest ecosystem, two major pathways of flux should be recognised namely : (i) Biological (closed cycle) and (ii) Geochemical (open) cycle. The biological cycle may involves a cyclic circulation of nutrients between the forest soil and the biotic communities and may includes the processes of mineral uptake (or) absorption, retention (in the annual accumulation of biomass) and restitution (or) losses (Leaf litter, organic debris, washing by rain etc.) (Duvigneud and Denayer De Smit 1970). This may be expressed as below.

Nutrient uptake = Nutrient retention + Nutrient returned.

In this chapter, the nutrient cycling for 4, 5 and 6 year old plantation bamboo has been worked out from the data on biomass, productivity, nutrient content, litter production and nutrient in litter etc.

1. NUTRIENT UPTAKE

The nutrient content in the current annual production in 4, 5, and 6 year old plantation bamboo was worked out. This may in fact the annual nutrient uptake. It may be mentioned here, that these figures may be obtained by multiplying the productivity figures of 4, 5 and 6 year old plantation by the concentration of various nutrients in their respective biomass components.

The maximum amount of all nutrients per hectare, occurred in the culms, followed by branches, rhizomes and leaves. It may seen that, the nutrient content in the current annual production amount to 1079, 103, 1122, 505 and 603 kg/ha^{-1}, (4 year), 1986, 201, 2067, 982 and 1014 kg/ha^{-1} (5 year) and 2615, 238, 2386, 1302 and 1452 kg ha^{-1} (6 year) of N, P, K, Ca and Mg respectively. Harvesting above ground biomass would result in the removal of all the nutrients.

Rennie (1955) drew attention that when considerable amount of nutrients immobilized in the crop, the nutrient supply is required to maintain continuous timber production by poorer soil. A considerable amount of nutrients may be tied up in the aerial organs of the bamboo and some advantages could be gained over several rotations by leaving foliage on the site at the time of harvest during the dormant season (or) may defoliate trees during the growing season (Switzer and Nelson, 1972, and Tandon, *et al.*, 1988).

It may seen that, the nutrient content in bamboo found higher, which may be due to regular irrigation and application of fertilizers, consequently resulting in a higher nutrient accumulation. In plantation bamboo excluding rhizomes, all other biomass components with their nutrients may removed, while harvesting these plantations. Hence, necessary precautions need be observed, while exploiting large scale plantation to maintain the fertility status of soil.

2. NUTRIENT RETAINED

The nutrients retained in the average annual production may be obtained by multiplying the increase in biomass components with their respective nutrient concentration. The nutrient contents of the standing crop differs substantially between various forest types according to the degree of uptake and crop biomass, which may inturn depend on tree age and site quality, even within the same species. The increase in nutrient contents of the standing crop with stand age observed in plantation bamboo, should have a direct relationship to the total biomass of a forest stand (Roddin and Bazilevich 1967). As such, the nutrients accumulated in various tree components may vary considerably. It may observed that on an unit area basis the maximum amount of all nutrients found in the culm followed by the

branches, rhizomes and leaves. Therefore, maximum drains of K occurs followed by N, Mg, Ca and P similar to *Dendrocalamus hamiltonii* (Toky and Ramakrishnan 1983).

In *Bambusa tulda, Neohouzeau dulloa and Bambusa khasiana* the maximum retention may be in the order of K, N, Ca, Mg and P (Rao and Ramakrishnan, 1989). Since the annual nutrient content may usually followed by biomass growth (average annual production), it may increases linearly during the period of rapid growth and may diminishes at maturity (Pritchett, 1979). The same holds true for *Bambusa bambos* plantations, where the average annual production found maximum at 6 years of age and similarly the annual accumulation of nutrients also attains a peak value. These results in general agreement with earlier observations (Wells and Jorgenson, 1975; Negi and Sharma, 1984).

The nutrient retention in *Bambusa bambos* plantations are not within the values obtained in other plantations, e.g. *Pinus radiata* (Madgwick *et al.*, 1977), *P. banksiana* (Foster and Morrison, 1976), *P. kesiya* (Das and Ramakrishnan, 1987), *Eucalyptus hybrid* (Negi 1974; George, 1977), *E. grandis* (Turner and Lambert 1981) and *E. marginata* (Hingston *et al.*, 1981). but may found to be 14-85% higher. This may be due to the higher number of culms in *Bambusa bambos*.

3. NUTRIENT RETURN

Estimation of litter production and nutrient return was carried out. (Table 38-42). It may observed that 120, 10, 101, 60, and 66 Kg/ha (4 year), 141, 13, 121, 72, and 79 kg/ha (5 year) and 184, 16, 183, 91 and 96 kg/ha (6 year) of N, P, K, Ca and Mg may returned through litter fall. The maximum amount of all nutrients may returned through leaf litter and minimum by twig litter. It may observed that of the total litter (15 t/ha) in the 4th year 60% may contributed by the leaf and 40% by the twigs. However, during the 5th (18 t/ha) and 6th years (18 t/ha), 58% may contributed by the leaf and 42% by the twigs. With regard to nutrient return, nearly 60-70% may be returned through the leaf-litter and the rest by twigs.

4. NUTRIENT CYCLING

On the basis of the above results, nutrient cycling in the plantation on an annual basis was calculated. (Table 43). Of the total uptake of nitrogen, 89% may retained while 11% may returned to the soil. Similarly, 90% of total phosphorus may retained and 10% returned. With regards to K, Ca and Mg 91% 89% and 89% may retained and 9%, 11% and 11% may return respectively in the 4th year. In the 5th and 6th years, of the total uptake of nitrogen,

Table 38. Litter production (Kg/ha) on unit area basis in *Bambusa bambos* plantation

Months	4 Year			5 Year			6 Year		
	Leaf	Twig	Total	Leaf	Twig	Total	Leaf	Twig	Total
Jan.	720 ± 10.5	540 ± 7.5	1270	865 ± 40.5	635 ± 15.0	1500	982 ± 45.0	759 ± 15.0	1741
Feb.	650 ± 11.5	510 ± 10.5	1160	733 ± 28.3	604 ± 13.0	1337	817 ± 30.5	668 ± 13.0	1485
Mar.	560 ± 9.0	530 ± 8.0	1090	655 ± 27.5	639 ± 11.5	1294	710 ± 31.0	693 ± 13.5	1403
April	580 ± 8.5	460 ± 10.5	1040	694 ± 41.8	550 ± 19.5	1244	784 ± 45.8	619 ± 17.0	1403
May	1080 ± 10.7	570 ± 7.4	1650	1138 ± 30.5	658 ± 9.5	1796	1320 ± 33.5	767 ± 9.5	2087
June	925 ± 9.5	540 ± 6.8	1465	974 ± 15.5	632 ± 13.5	1607	1106 ± 18.5	718 ± 10.0	1824
July	575 ± 15.5	460 ± 8.5	1035	697 ± 15.5	552 ± 16.0	1249	809 ± 40.5	635 ± 19.5	1444
Aug.	590 ± 13.5	530 ± 7.5	1120	706 ± 20.5	643 ± 19.2	1349	833 ± 20.5	767 ± 13.0	1600
Sept.	665 ± 14.0	485 ± 9.5	1150	725 ± 30.5	882 ± 30.2	1307	875 ± 25.0	677 ± 14.5	1552
Oct.	585 ± 11.5	450 ± 11.5	1035	671 ± 41.5	548 ± 10.5	1219	759 ± 30.5	627 ± 10.5	1386
Nov.	795 ± 10.5	565 ± 9.0	1360	893 ± 38.9	666 ± 18.4	1559	1023 ± 21.5	776 ± 20.5	1799
Dec.	1465 ± 16.5	560 ± 6.5	2025	1556 ± 42.5	664 ± 21.5	2220	1815 ± 25.0	767 ± 21.0	2582
Total	9200	6200	15400	10307.0	7373.0	17680.0	11833	8473	20306

Table 39. Nutrient concentration in litter components (%) of *Bambusa bambos*

Nutrient (%)	4 Year		5 Year		6 Year	
	Leaf	Twig	Leaf	Twig	Leaf	Twig
N	0.91 ± 0.50	0.58 ± 0.42	0.94 ± 0.20	0.61 ± 0.59	0.97 ± 0.54	0.82 ± 0.54
P	0.08 ± 0.05	0.05 ± 0.40	0.09 ± 0.05	0.06 ± 0.01	0.08 ± 0.0	0.08 ± 0.05
K	0.63 ± 0.50	0.70 ± 0.54	0.65 ± 0.10	0.73 ± 0.54	0.93 ± 0.27	0.86 ± 0.10
Ca	0.45 ± 0.7	0.31 ± 0.51	0.47 ± 0.50	0.33 ± 0.49	0.48 ± 0.24	0.40 ± 0.39
Mg	0.47 ± 0.50	0.37 ± 0.41	0.49 ± 0.54	0.39 ± 0.51	0.51 ± 0.30	0.43 ± 0.10

Table 40. Nutrients return through litter fall (kg/ha) in *Bambusa bambos*

Nutrients	Litter components								
	4 Year			5 Year			6 Year		
	Leaf	Twig	Total	Leaf	Twig	Total	Leaf	Twig	Total
N	84	36	120	96	45	141	115	69	184
P	7	3	10	9	4	13	9	7	16
K	58	43	101	67	54	121	110	073	183
Ca	41	19	60	48	24	72	57	34	91
Mg	43	23	66	50	29	79	60	36	96

Table 41. Annual release of Nutrients (kg/ha^{-1}) through litter fall in different forest ecosystems

Forest type & Locality	Nitrogen	Potassium	Phosphorus	Calcium	Magnesium	Source
Spruce (USSR)	52	12	2	48		Singh, 1960
Birch (USSR)	66	13	5	54		Smirnova and Corodentseva 1958
Oak (USSR)	59	62	3	86		Mina, 1955
Eucalyptus tereticornis (U.P. India)	14.2-34.5	–	8.6-20.8	98.2-334.5		Singh, 1984
Tectona grandis (U.P. India)	82	19	11	131		Seth et al. 1963
Shorea robusta (U.P. India)	46	19	9	77		–do–
Pinus spp (U.P. India)	73	39	13	46		–do–
Butea spp. (U.P. India)	18	6	0.3	5		Singh, K.P. 1968
Piecea Smithiana (H.P. India)	46.53	13.61	10.21	56.17		Singh et al. 1984
Cedrus deodara (H.P. India)	47.78	16.86	28.81	70.97		–do–
Abies pindrow (H.P. India)	40.69	9.0	15.16	52.78		–do–
Pinus wallichiana (H.P. India)	24.45	6.03	7.93	34.93		–do–
Bambusa bambos plantation (India)						
4 Year	120.0	101.0	10.0	60.0	66.0	Present study
5 Year	141.0	121.0	13.0	72.0	79.6	Present study
6 Year	184.0	183.0	16.0	91.0	96.0	Present study

phosphorus, calcium and magnesium 93% was retained and only 7% was returned. Thus it may seen that Bamboos may retains more nutrients than it returns. The results of nutrient cycling in bamboo may emphasize the importance of the application of external fertilizers after the harvest of biomass components.

Table 42. Release of nutrients during leaf decomposition (%)

	Nutrient				
Month	N	P	K	Ca	Mg
January	0.95	0.10	0.60	0.45	0.49
February	0.92	0.10	0.58	0.43	0.48
March	0.90	0.10	0.57	0.42	0.47
April	0.88	0.10	0.54	0.41	0.45
May	0.82	0.09	0.50	0.33	0.42
June	0.78	0.09	0.45	0.30	0.40
July	0.72	0.09	0.38	0.27	0.28
August	0.67	0.08	0.31	0.24	0.30
September	0.58	0.08	0.26	0.20	0.26
October	0.49	0.08	0.20	0.18	0.20
November	0.45	0.08	0.17	0.16	0.18
December	0.43	0.08	0.13	0.15	0.16

Release of nutrients during leaf decomposition was determined. The results expressed are average of three independent experiments. The nutrient release was found in the orer of K>C_2>Mg>N>P.

Table 43. Nutrient cycling in 4th year *Bambusa Bambos*

Nutrient	N	P	K	Ca	Mg
Retained	959.0	093.0	1021.0	445.0	537.0
Returned	120.0	10.0	101.0	60.0	66.0
Uptake	1079.0	103.0	1122.0	505.0	603.0
Nutrient cycling in 5th year *Bambusa bambos* Plantation					
Retained	1845.0	188.0	1946.0	910.0	1035.0
Returned	141.0	13.0	121.0	72.0	79.0
Uptake	1986.0	201.0	2067.0	982.0	1014.0
Nutrient cycling in 6th year *Bambusa bambos* Plantation					
Retained	2431	222	2653	1211	1356
Returned	184	16	183	91	96
Uptake	2615	238	2836	1302	1452

The nutrient cycling of *Bambusa bambos* plantation at the age of 4th year was worked out. Of the total uptake of all nutrient nearly 93% was retained and only 7% was return by litter fall.

This study was compared with various plantation ecosystems. It may seen that, unlike in *Pinus patula* (Bhartari 1986), *Dalbergia sissoo* (Sharma *et al.*, 1985), *Eucalyptus grandis* (Turner and Lambert 1983) and *E. globulus* (George and Varghese 1990a), in *Bambusa bambos* nutrients are utilized more than returned.

CHAPTER 11

PULP AND PAPER CHARACTERS

Bamboo is considered to be an unique raw material from the point of its quick growth, easy availability, straightness, smoothers etc. It may used for various purposes such as construction of rural houses, ladders, mats, baskets, pipes, handicrafts etc. But the largest demand may be for the manufacture of paper. During the last few decades, it has become a major source of raw material for the Indian pulp and paper industry. The paper industry has an installed capacity of 0.3 million tonnes, covering 316 small, medium and big paper mills and may produced about 2.75 million tonnes of paper board during the year 1992 (Adkoli, 1990).

The industry is presently facing problems of non availability of suitable fibrous raw materials in adequate quantity to meet its requirements. The supply of bamboo so for the main raw material for the Industry, has been dwindling in the recent years. Sustained availability can be ensured only by elaborate cultivation of bamboo. Still bamboo accounts for 60% of the fibrous raw material requirement of the Industry. In order to meet the present and future requirements of the paper industry, efforts may be needed not only to improve productivity, but also to use the existing bamboo resources judiciously and efficiently.

During the extraction of bamboo from the forest no definite cutting age is maintained. Rather, bamboos of different age groups may extracted indiscriminately. As a result pulping of a mixture of

bamboos of different age groups may result in heterogeneous cooking, producing inferior quality of pulp. To over come these problems, a study need be undertaken to observe the optimum age for felling the plantation bamboo for pulp and paper making. This will help to determine an optimum cutting cycle for the species under investigation. (Shanmughavel 1995). Various workers Razzaque *et al.*, 1981 (*Melocanna baccifera, Oxytenanthera nigrociliata, Dendrocalamus longispathus, Bambusa tulda* and *Neohouzeaua dulloa*, Bose *et al.*, 1988) (*Melocanna baccifera*), Maheshwari and Satpathy (1988) *Dendrocalamus strictus* and Kasim *et al.*, (1993) (*Gigantochloa scortechnii*) already reported the influence of age of bamboo on pulping.

The salient points of which are given below :

(a) Fibre Characters

The fibre length may ranged from 2 mm in the first year to 2.6 mm in the tenth year (Table 44). The fibre classification of both unbleached and bleached pulp are presented (Table 45 and 46). Similar to fibre length, fibre content in different mesh may varied in its per cent. In unbleached pulp the per cent content of +50 mesh fibres may varied from 68.1 per cent in first year to 69.97 per cent in tenth year, +65 mesh fibres from 7.44 per cent to 8.93 per cent, +100 mesh fibres from 3.72 per cent to 3.84 per cent, -100 mesh fibres from 18.88 per cent to 19.1 percent. In bleached pulp the per cent content of +50 mesh fibres may found varied from 76.1 per cent to 80.7 per cent, + 65 mesh fibres 9.39 per cent to 9.9 per cent, + 100 mesh fibres from 5.10 per cent to 5.51 per cent and -100 mesh fibres from 4.39 per cent to 5.10 per cent.

The fibres are sclerenchymatous tissues and may occur as caps over vascular bundles as isolated strands. They may long and tappered at both ends. Good tear, burst, tensile and folding endurance may be the requisites of good quality paper. This may vary with the fibre length and diameter as well as their ratio. The fibre length may influence the physical and mechanical properties which inturn affect the workability (Zamuco *et al.*, 1969, Britt, 1970, Paramasivan and Liese, 1976, Espiloy, 1987, Latif and Mohd. 1992 and Jamaluddin and Latif, 1993). The fibre length of bamboo may varies from species to species and in some within internodal length (Pattanath, 1972). In plantation, it may be interesting to note that, no appreciable change could be monitored with increase in age. The fibre length obtained may ranges between 2mm to 2.6 mm in 1 and 10 year old *Bambusa*

Table 44. Fibre length in *Bambusa bambos*

Age in Years	1	2	3	4	5	6	7	8	9	10
Bamboo density (gm/cc)	0.588	0.593	0.598	0.610	0.617	0.622	0.628	0.631	0.634	0.639
Average fibre length (mm)	2.0	2.0	2.3	2.3	2.5	2.5	2.5	2.5	2.6	2.6
Chips density (BD) kg/m3	200.41	202.10	208.10	215.00	220.10	224.76	224.78	224.78	224.80	224.80

Fibre length was determined. The results expressed are average of three independent experiments. There was no significant variation in the fibre length of 1st year (2mm) to 10th year (2.5 mm) bamboo.

Table 45. Fibre classification (unbleached pulp)

Fibre classification	Age in years									
	1	2	3	4	5	6	7	8	9	10
+50 mesh fibre (%)	68.10	68.90	69.10	69.80	69.96	69.96	69.96	69.96	69.97	69.97
+65 mesh fibre (%)	7.44	8.10	8.42	8.92	8.92	8.92	8.92	8.92	8.92	8.983
+100 mesh fibre (%)	3.72	3.74	3.80	3.83	3.83	3.83	3.83	3.83	3.83	3.84
–100 mesh fibre (%)	18.88	18.96	19.00	19.09	19.09	19.10	19.10	19.10	19.11	19.11

Fibre classification of unbleached pulp was made. The results expressed are average of three independent experiments. All the fibre per cent found to be increased with age.

Table 46. Fibre classification (Bleached pulp)

Fibre classification	Age in years									
	1	2	3	4	5	6	7	8	9	10
+50 mesh fibre (%)	76.10	78.20	79.12	80.27	80.40	80.70	80.70	80.70	80.71	80.71
+65 mesh fibre (%)	9.39	9.42	9.63	9.70	9.89	9.90	9.90	9.90	9.91	9.91
+100 mesh fibre (%)	5.10	5.24	5.40	5.42	5.50	5.51	5.51	5.51	5.51	5.51
−100 mesh fibre (%)	4.33	4.53	4.62	5.00	5.10	5.10	5.10	5.10	5.10	5.10

Fibre classification of unbleached pulp was made as described. The results expressed are average of three independent experiments. All the fibre per cent found to be increased with age.

bambos. The influence of fibre on the physical properties of pulp have been reported by many scientific studies. (Tamolong, 1960, Zamuco *et al.*, 1969 and Jamaluddin and Latif, 1993). There may be three principal factors affecting the pulp strength; fibre density, fibre length and fibre strength (Dinwoodie, 1965).

Fibre density may be associated with cell wall thickness; (or) the ratio of cell wall thickness to fibre diameter (or) ratio of lumen diameter to fibre diameter and together with Runkel ratio, they may predetermine and dictate the tensile, bursting strength and folding endurance of the paper produced. Fibre length and fibre strength on the other hand may essential for fibre bonding. As such, for instance, tearing strength may depends upon fibre length (Clark 1948, Wangaard, 1962), fibre strength and cell wall thickness (Dinwoodie 1965).

Fibre length of forest bamboo was well documented (Razzaque *et al.*, 1981, Latif and Mustafa, 1992, and Jamaluddin and Latif, 1993). Fibre length need be an important criterion in identifying the fitness of the wood in pulping as it may have direct correlation with the tearing strength of the paper (Bublitz 1980). Plantation *Bambusa bambos* may attain its maturity during the first year of growth, the fibre length may slowly increases with age which may vary between species (Latif and Mustafa 1992; Razzaque *et al.*, 1981 and Jamaluddin and Latif 1993). The fibre length within and between bamboo culm may remain as an individual characteristics (Grossar and Lisse, 1974, Pattanath, 1972; Espiloy, 1987, Widjaja and Risyed 1987, Guha *et al.*, 1975; Siddique and Chowdhury 1985 and Maheshwari and Satpathy, 1988).

Fibre obtained from plantation bamboo forests may found shorter in length while comparing with those from counterparts in natural forests (*Bambusa polymorpha* (4.19 mm), *Dendrocalamus giganteus* (3.69 mm), *D. hamiltonii* (3.36 mm) and *Oclandra travancorica* (4.03 mm) (Tewari, 1992).

Analogous to fibre length, the per cent content of +50, +65, +100 and -100 mesh fibres does not vary remarkable in unbleached and bleached pulp. The life cycle of the bamboo culm will account for some of the variations. It may conceivable that, external factors such as soil conditions and climatic changes during fibre development might influence the fibre length.

(b) Proximate chemical analysis

The chemical analysis of 1st year to 10th year old *Bambusa bambos* may showed gradual minimal increasing trends in the

chemical components studied (Table 47). The ash content may varied from 1.20 per cent in the 1st year to 2.30 per cent in the 10th year. Other properties may include cold water solubles (4% to 4.5%), hot water solubles (4.47% to 5.95%), alcohol-benzene solubles (7.50% to 8.0%), 1% NaOH solubles (20.5% to 23.5%), pentosans (19.10% to 20.20%), lignin (28% to 32%), cellulose (60.10% to 65.6%) and moisture (40% to 50%).

The chemical analysis of *Bambusa bambos* revealed gradual increase in the distribution of chemical components with age, similar to *Bambusa bambos, B. polymorpha, B. tulda. Dendrocalamus hamiltonii, D. longispathus, D. strictus, Melocanna baccifera* and *Schizostachyum dulloa* (Guha, 1980, Maheshwari and Satpathy 1988).

Generally, bamboo species with higher holocellulose may have lower cold and hot water solubles, but with lower lignin content may have higher cold and hot water solubles. Bamboo with higher holocellulose and lower lignin content may be better suited for pulp and paper (Chen *et al.*, 1985 and Escalano, 1973). In plantation bamboo, proportionate increase ot lignin with age was observed (28% in 1 year to 32% in 6 year). Corresponding increase in holocellulose, lignin and ash contents with age were reported by Maheshwari and Satpathy, 1988 and Jamaluddin *et al.*, 1992. However, comparatively lower lignin content were reported within the range of 25% to 28% (Semana *et al.*, 1967, Peh *et al.*, 1986 and Jamaluddin and Mohmod, 1992). The higher lignin content may indicates the need of more chemical consumptions during bleaching.

(c) Pulp and paper making characters

It may observed that, the bleachable grade pulp yield ranged from 46.36% in the 1st year to 48.80% in the 10th year (Table 48). The physical strength properties of unbleached pulp showed that the burst factor, tear factor, breaking length and double folds may increase from 1 to 10 years Table 49. The bleachability test showed that the pulp may requires 8.91% to 10.49% chloride for getting final 75% brightness in the 1 year and 84% in the 10th year (Table 50).

The bleaching loss decreased from 14.04% and 13.63% in the 1st and 10th year respectively. The physical strength properties of bleached pulp may reveals that burst factors, tear factor, breaking length, and double folds may showed a gradual increase from 1st year to 10th year (Table 51). The black liquor characteristics such as total solids, in organic content, acid solubles, sodium oxide, Swelling Volume Ratio (SVR) may also increased with age. (Table 52).

Table 47. Proximate chemical analysis of *Bambusa bambos*

Age in years	Ash (%)	Cold water solubles (%)	Hot water solubles (%)	Alcohol benzene solubles (%)	1% NaOH solubles	Pentosans (%)	Lignin (%)	Cellulose (%)	Moisture (%)
1	1.20	4.00	4.47	7.50	20.50	19.10	28.00	60.01	40.0
2	1.50	4.00	4.60	7.50	21.90	19.32	28.50	61.20	40.0
3	1.70	4.20	4.90	7.90	22.50	19.53	29.00	62.50	45.0
4	1.90	4.20	5.10	8.00	023.00	19.62	30.50	63.30	50.0
5	2.10	4.30	5.80	8.00	23.00	20.33	31.50	64.50	50.0
6	2.30	4.50	5.95	8.00	23.50	20.20	32.00	65.60	50.0
7	2.30	4.50	5.98	8.00	23.50	20.21	32.10	65.60	50.0
8	2.31	4.52	5.98	8.05	23.52	20.21	32.05	65.65	50.0
9	2.30	4.50	5.95	8.00	23.50	20.20	32.00	65.63	50.0
10	2.30	4.50	5.95	8.00	23.50	20.20	32.00	65.60	50.0

The first year to tenth year old culms were harvested for studying their proximate chemical composition. The results are the average of the three independent experiments. Gradual minimal increasing trends of all the proximate chemical components was noticed.

Table 48. Pulping data

Characteristics	Age in Years									
	1	2	3	4	5	6	7	8	9	10
Total pulp yield (%)	46.36	47.23	48.10	48.30	48.44	48.80	48.80	48.81	48.80	48.80
Knots (%)	2.27	2.19	2.24	2.26	2.30	2.30	2.31	2.33	2.32	2.30
Kappa number	27.20	27.60	27.60	28.90	28.90	28.90	28.92	28.92	28.90	28.90

Total pulp yield, knots and kappa number was calculated. The pulp yield found to be increased from (1st year) to 48.80% (10th year)

Table 49. Physical strength properties of unbleached pulp

Characteristics	Age in years									
	1	2	3	4	5	6	7	8	9	10
Burst factor	47.8	48.0	48.2	48.9	49.0	49.1	49.1	49.2	49.1	49.1
Tear factor	80.0	82.0	84.0	85.0	86.0	86.5	86.5	86.5	86.6	86.5
Breaking length (m)	6706.0	6780.0	6990.0	7210.0	7222.0	7222.0	7222.0	7223.0	7222.0	7222.0
Double folds	85.0	95.0	120.0	150.0	160.0	180.0	180.0	181.0	180.0	180.0

Physical strength properties of unbleached pulp were made. The results expressed are average of three independent experiments. The physical strength properties increased with age.

Table 50. Bleachability test

Characteristics	Age in Years									
	1	2	3	4	5	6	7	8	9	10
Initial brightness (%)	30.0	30.0	32.0	33.0	33.0	33.0	33.0	33.00	33.00	33.00
Final brightness (%)	75.0	76.0	78.0	80.0	80.0	84.0	84.0	85.00	85.00	85.00
Cl2 consumption	8.91	9.10	9.49	10.0	10.49	10.49	10.49	10.49	10.49	10.49
Bleaching loss (%)	14.04	13.57	13.57	13.57	13.60	13.63	13.63	13.64	13.63	13.63

The bleachability test was carried out. The results expressed are average three independent experiments. The chloride consumption for bleaching increased with age. The bleaching loss also increased with age.

Table 51. Physical strength properties of bleached pulp

Characteristics	Age in Years									
	1	2	3	4	5	6	7	8	9	10
Brust factor	37.5	38.0	42.5	42.5	43.5	44.0	44.0	45.0	44.0	44.0
Tear factor	63.9	64.9	66.7	68.0	68.9	68.9	68.9	68.9	68.10	68.9
Breaking length (m)	4933.0	5011.0	5316.0	5410.0	5415.0	5415.0	5415.0	5416.0	5415.0	5415.0
Double folds	70.0	85.0	90.0	120.0	130.0	140.0	140.0	141.0	140.0	140.0

The physical strength properties of bleached pulp was carried out. The results expressed were average of three independent experiments. The physical strength properties increased with age.

Table 52. Black liquor analysis

Characteristics	Age in Yeras									
	1	2	3	4	5	6	7	8	9	10
Total solids (gpl)	200.00	205.1	206.0	208.0	209.0	209.0	209.0	209.0	209.0	209.0
Inorganics (%)	46.90	47.69	47.67	48.10	48.33	48.33	48.33	48.33	48.30	48.33
Organics (%)	51.67	51.90	52.80	52.90	52.91	52.91	52.91	52.92	52.91	52.91
Acid. insolubles (gpl)	4.20	4.37	4.90	5.10	5.50	5.50	5.90	5.51	5.50	5.50
Na2O (gpl)	54.14	54.20	54.64	055.10	55.17	55.19	55.19	55.19	55.20	55.20
Swelling volume ratio (ml/gm)	25.0	25.0	26.0	27.0	27.0	27.0	27.0	27.0	27.1	27.0
Calorific value (cals/gm)	3795.0	3810.0	3894.0	3910.0	3960.0	3968.0	3968.0	3969.0	3969.0	3968.0

The balck liquor analysis was carried out. The results expressed are average of three independent experiments.
The characteristics studied were increased with age.
gpl - gram per litre; gm - gram; Cals-calories.

The bleachable grade pulp yield ranges between 46.36% and 48.80% which may comparable with 42-48% of the sulphate process (Chao and Pan 1972) and 45-53% of Kraft pulping (Kasim *et al.* 1993). While cooking may be done separately for each age group, a minimum of 19% alkali may required to get a pulp having a kappa number of 27+2. Based on the percentage yield if stationary digester charged with 20 tonnes bamboo chips with 18-19% alkali, keeping other parameters constant, the output would be 8.7 to 9.0 tonnes of pulp. Good tear, burst, tensile and folding endurance, values may be the requisites of a good quality paper. The physical strength properties of the pulp may found to be unaffected by the age of bamboo (Razzaque *et al.*, 1981, Maheshwari and Satpathy 1988).

The pulp may requires only 8.91 to 10.49% chlorine for bleaching to develop a brightness of 75% to 84%. The bleaching loss may varies from 14.04% to 13.57% which may decreases with age. In the bleached pulp all the physical strength properties may increased with age. The increase in breaking length on both unbleached and bleached pulp could be attributed to the increase in fibrillation, which leads to fibre bonding (Casey, 1980, Kasim *et al.*, 1993). Tearing resistance on the other hand, may depends entirely on the fibre length (Wangaard and Woodson, 1973). The black liquor analysis indicated that, the total solids obtained may ranges from 200-209, the inorganics 46.90% to 48.33%, the acid insolubes from 4.20 gpl to 5.50 gpl. The Swelling Volume Ratio of all ages may be more than 25 ml/g. The calorific value may ranges from 3795 cal/gm (1 year) to 3968 cal/gm (6 year).

In plantation crop though no appreciable change in chemical composition of pulps could be monitored with increasing age, these bamboo species may attain maturity during the first year of growth. Hence, one to six year old culms can be used as raw material for pulping. However, in order to get higher annual recruitment of culms in the subsequent years it may recommended that, 36 months cutting cycle is ideally suitable for pulping purposes. Bose *et al.*, (1988) suggested a cutting cycle of 21 months for muli bamboo (*Melocanna baccifera*) from the point of yield gain. Biennial felling cycle has also been observed to give maximum yield and superior quality pulp in case of *Dendrocalamus strictus*. From management point of view biennial felling cycle does not cause any serious difficulties (Mohan 1931). Youdi *et al.*, (1995) also concluded for ten bamboo species that the bamboos should not be older than 36 months for chemical utilisation if practice of cultivation and rotation are considered.

CHAPTER 12

METHODOLOGY

Preparation of nursery and planting

Nursery area should be filled with a mixture of soil and sand (3:1). Seedlings, raised by tissue culture techniques are preferable and suitable. The seedlings are available from Chithode, near Erode, Tamil Nadu State, India and should be removed from their polythene bags, when they were about 7 cm in height. About 25 to 30 seedlings need be transplanted in one square metre of raised nursery bed and irrigated 2 to 3 times a day taking care to avoid excess saturation. Nursery beds should be provided with a coconut thatch to protect the seedlings from direct sunlight.

Transplantation

The seedlings in the nurseries should be uprooted carefully and transplanted to the field during August. The seedlings need be planted at 6m x 6m spacing. The transplanted seedlings should be irrigated two hours regularly both in the morning and evening. Weeds should be removed from the plantation area as and when required. After one year, the plantation should be adequately irrigated at 15 days interval. Care should be taken to avoid waterlogging and protected against rodents, grazing and browsing animals.

Production of culms

All transplanted seedlings may produce rhizomes. From these

rhizomes lateral culms will be emerging which are the chief causatives for the total biomass yield. The number of culms produced from the rhizome totally constituted to a clump. The productivity of bamboo may be assessed by the number of new culms produced annually. At a given site the production of new culms may be mostly dependent on the culms of the previous year, the degree of congestion and the clump age.

1. GROWTH STUDIES

(i) Counting

The number of clumps and culms presented in the entire study areas should be counted.

(ii) Growth measurement

From each hectare fifteen clumps should be randomly selected from the plantation and should be identified with paint marking. Number of culms presented in these selected fifteen clumps need be counted. New culms sprouting from the selected clumps should be taken for growth measurements. In each clump, five newly sprouted culms should be marked with paint, totalling 150 observations. On alternate days the height of each culm need be measured and only after reaching 1.37 m height, the diameter at breast height (DHB) should be recorded. All observations should include, the basal area girth, DBH and growth in height on all culms.

(iii) Monthly recruitment of culm

From the same study area, another set of fifteen clumps should be randomly selected from the plantation for the assessment of monthly recruitment of culm. Every month, the number of newly sprouted culms and their survival need be recorded. The observation should be continued for full one year.

(iv) Pattern of biomass allocation in growing Bamboo

The pattern of biomass allocation may be studied from the young sprouted bamboo (culm) reached a height of 12 cm. At one week regular interval, these young bamboos need be felled and their height should be recorded. Each young bamboo after fully differentiated with culm, branch and leaves, the whole unit should be felled, and these components need be separated individually. Their fresh weight will be determined in the field and all the subsamples should be brought to

the laboratory filling in plastic bags. They should be oven-dried to remove all moisture at 103 + 2°C to a constant weight. From moisture free oven-dry weight of these samples, the dry weight of each three component and their total weight may be calculated.

(v) Biomass estimation

In order to estimate the total biomass in relation to organic productivity fifteen culms should randomly selected from each age groups of plantations. The selected culms need be felled to a total of ninety. For economy reasons, rhizome should be excavated only from three samples to a total of eighteen. After felling, the total height of each culm, DBH basal diameter, number of nodes need be measured and should be subdivided into four main components, leaves, branches, culm (bole) and rhizome. A total of 18 rhizomes 3 from each year of plantation need be excavated for determination of underground biomass. It may be done by making a trench around the culm. Fresh weight of the components need estimated in the field and sub-sample from each component should be brought to the laboratory in plastic bags. The sub-samples should be oven-dried at 103 + 2°C to a constant weight.

From the oven-dry weight of the sampels, the total standing biomass (t/ha) of each age group may be calculated by multiplying the total number of the bamboos of different ages with the average dry weight of the sample. The annual biomass production (total biomass divided by age) and mean periodic production (the difference between biomass measurement of two stands in a - sequence divided by the age interval) and net primary productivity may be estimated from the biomass studies.

2. BIOCHEMICAL ANALYSIS

(i) Extraction of chlorophyll

The chlorophyll should be estimated by the method of Arnon 1959. One gram of the fresh sample need be homogenized in excess of acetone (100%) in a mortar with pestle. It should be filtered through Buchner's funnel, using Whatman No. 42 filter paper. The extraction need be repeated with 80 per cent acetone. The content of mortar should be transferred to the Buchner's funnel and need be washed with acetone till the brief appeared colourless. The filtrate than pooled and make upto 100 ml in a volumetric flask. From this 5 ml of the solution need be transferred to a 50 ml volumetric flask and should be further diluted by making up to the volume with 80 per cent acetone.

(ii) Estimation of chlorophyll

The absorbance of 80 per cent acetone extract need be measured at 645 and 663 nm using a light path of the one centimetre. The concentration of total chlorophyll, chlorophyll 'a' and chlorophyll 'b' should be calculated using the following formula:

$$\text{Total chlorophyll (mg/g)} = \frac{20.2\ A645 \times 8.02\ A663}{a \times 1000 \times w} \times v$$

$$\text{Chlorophyll 'a' (mg/g)} = \frac{12.7\ A663 \times 2.69\ A645}{a \times 1000 \times w} \times v$$

$$\text{Chlorophyll 'b' (mg/g)} = \frac{22.9\ A645 \times 4.68\ A663}{a \times 1000 \times w} \times v$$

v = volume of the extract in ml

w = fresh weight of the sample in grams

(iii) Carotenoids

The concentration of total carotenoids in the 80 per cent acetone extract should be calculated according to Goodwin (1954) using the following formula.

Total carotenoids (μg/ml) = A480 + (0.114 x A663 - 0.638 x A645)

Extraction and estimation of total soluble carbohydrate

(iv) Extraction of total soluble carbohydrate

Extraction of total soluble carbohydrate should be done by the method of Lee and Toursean (1958).

One gram of plant material need macerated gently with 1.5 of 80 per cent ethanol (w/v) and should be extracted over a boiling water for 10 minutes. The ethanol extract need be allowed to cool and should be filtered through Whatman's No. 41 filter paper. The residue need be re-extracted with 80 per cent ethanol for four times in succession. The filtrate need be combined and should be washed with petroleum ether until colourless. The pigment free alcohol need be evaporated over a boiling water bath and the residue should be redissolved in 80 per cent ethanol to a known volume.

(v) Estimation of total soluble carbohydrate

The carbohydrate should be measured by the method of Dubois *et al.*, (1951) using known amounts of glucose as standard in spectrophotometer at 625 nm. An aliquot of 1 ml of extract need be taken in a test tube to which 8 ml of distilled water and 6 ml of anthrone reagent should be added (Anthrone reagent may be prepared by dissolving 200 mg of anthrone in 100 ml of concentrated sulphuric acid). A glass marble should be kept on the top of each test tube to prevent loss of water by evaporation. The tubes need be treated over a boiling water bath for 10 minutes and should be cooled to room temperature. The absorbance of a blue green solution need be measured at 625 nm using spectrophotometer. From a standard curve prepared with known amounts of glucose, the amount of total carbohydrates present in each sample may be calculated and the results should be expressed as mg/g fresh weight of the sample.

(vi) Estimation of Starch

Weighed quantity of leaves need be cut into small bits and should be ground vigorously in 80 per cent acetone and must be centrifuged at 3000 rpm for 5 minutes. The pellet need be re-extracted with 80 per cent acetone and should be centrifuged until the pellet should be devoid of green colour. The supernatant residue need be taken for starch analysis.

The method of McReady *et al.*, (1950) need be used to determine the soluble starch content. To the residue 6.5 ml perchloric acid and 3.5 ml of water should be added. The extract should be centrifuged at 3000 x g. The clear pellet need be used for the starch estimation. To 0.2 ml of sample, 5 ml of cold anthrone should be added and the volume should be made upto 10 ml with water. The contents need be mixed thoroughly and the absorbance should be measured at 600 nm Potato starch should be - used as standard.

(vii) Extraction of protein

The protein should be estimated by the method of Lowry *et al.* (1951). The Bovine serum albumin should be used as standard in spectrophotometer at 650 nm. One gram leaf need be homogenized in phosphate buffer (0.1 m pH 7.2) and should be centrifuged at 2000 x g for 30 minutes at 50°C. To the supernatant equal volume of 10 per cent trichloro acetic acid (TCA) need be added and allowed to stand for one hour in ice bath. The precipitate obtained should be re-dissolved in phosphate buffer (0.1 m pH 7.2) to estimate the concentration of protein content.

Reagent A : 2 per cent sodium carbonate in 0.1 N sodium hydroxide.

Reagent B : 0.5 per cent copper sulphate in 1 per cent potassiumsodium tartarate.

Reagent C : Alkaline copper solution, 50 ml of the reagent 'A' need be mixed with 1 ml of the reagent of 'B'. It should be used within a day of preparation. Diluted folin phenol reagent need be prepared by diluting folin-ciocalteau reagent 'C' (commercially) with an equal amount of distilled water.

(viii) Estimation of protein

One ml of the extract and 5 ml of the reagent 'C' should be taken in a test tube and should be allowed to stand for 10 minutes. Then 1 ml of diluted folin phenol reagent need be added and should be mixed and shaking. The solution need be allowed to stand for 30 minutes and the absorbance should be determined at 600 nm using spectrophotometer.

Regression equation

The regression equation should be derived using the method of Whittakar and Woodwell (1968). The data obtained in the productivity study need be fitted to the prediction equations. The linear prediction equations of total yield with one variable (diameter) or with two variables (diameter and height) should be computed with their co-efficient of determination (R2).

I. Regression equation with single independent variable (simple linear equation):

$\text{Log } Y = a + b \log X1$

$\text{Log } Y = a + b \log X2$

$\text{Log } Y = a + b \log X3$

$\text{Log } Y = a + b \log X4$

$\text{A Log } Y = a + b \log X5$

$\text{Log } Y = a + b \log X6$

Where Y = biomass (kg), X1 diameter, X2 square of diameter and height, X3 basal area and height, X4 height, X5 square of diameter and X6 basal area.

II. Regression equation with two independent variables:

Log Y = a + b1 log X1 + b2 log X2

Where, Y = biomass kg, X1 diameter, X2 height

III. Multiple regression equation

The prediction equation of total yield with more independent variables computed with their coefficient of determination (R2)/Log Y = a + b1 log X1 + b2 log X2 + b3 logX3 + b4 log X4 + b5 log X5 + b6 logX6.

Where Y = biomass (kg), X1 diameter, X2 height, X3 square of diameter, X4 diameter and height, X5 basal area and X6 basal area and height.

On the basis of co-efficient of determination (R2) the most suitable prediction equation should be selected for the prediction of total above ground yield.

(ix) Litter estimation

Nine litter plots with a size 1 x 5 m, should be laid down randomly throughout the sample plot. The litter plots need be made permanent by enclosing the area with nylon thread, which will last throughout the study period. The contents in the litter plots should be taken completely by the end of every month and should be separated into leaf and twig litter. Fresh weight need be estimated in the field and sub-samples of each component should be taken to the laboratory. The sub-samples should be oven dried at 80°C to a constant weight. From the sample oven dry weight, the total dry weight of the litter may be calculated.

(x) Litter decomposition

Both freshly fallen and senescent leaves need be collected and should be bagged in polythene bags with 5 mm perforation with a net weight of 50 gram. 50 bags of litter need be buried beneath the soil by removing one inch surface soil. Five bags of sample need be taken every month for a period of one year and the contents may be used for nutrient analysis.

3. ESTIMATION OF NUTRIENT ELEMENT

I. Nitrogen and Phosphorus

Nitrogen and Phosphorus may be estimated according to -

Armstrong *et al.*, (1967) using Technicon Autoanalyzer II (Gedko International Ltd., U.K.). The sample need be digested in a kjeldatherm digestion system KT 408 (Bonn) at 400°C for 3 hours. One gram sample should be digested in digestion tube with 2.5 g potassium sulphate and 5 ml. H_2SO_4. After digestion and cooling, digested sample should be make upto 50 ml with distilled water and may be used for analysis of nitrogen and phosphorus.

II. Potassium, calcium and magnesium

The nutrients K, Ca and Mg may be analyzed using an Atomic Absorption Spectrophotometer (Perkin Elmer 5000 U.S.A.) after wet digestion of one gram sample with triple acid mixture (10 ml of conc. HNO_3, 4 ml of HC104 and 1 ml of conc. HCl). The digested samples need be filtered through Whatman's No. 42 filter paper and should be make 100 ml with distilled water and this solution need be stored and should be used for analysis (Issac and Johnson 1975).

4. PROXIMATE CHEMICAL ANALYSIS

The analysis of wood, described by W.H. Dore (1931) may be followed.

Preparation of the sample

The bamboo need be reduced to sawdust by means of electrical saw. The saw dust may be sieved initially with 65 meshes and later with 200 meshes per s.q. cm. The material retained during the second sieving may be called "average wood" and should be used for the analysis (the wood used for the analysis may be done dry).

Procedure

I. Benzene extraction

7.0 gram of sample of average wood may be dried in a oven at 100°C. The dried content need be extracted with benzene for 6 hours in Soxhlet, the extract should be dried at 100°C and may be weighed.

$$\text{Benzene extract (\%)} = \frac{\text{Extract weight}}{\text{Bone dry wood weight}} \times 100$$

II. Alcohol extraction

The residue from the previous operation (Benzene extraction)

need be extracted for 6 hours with 95 per cent alcohol. The extract may be dried at a 100°C and should be weighed.

Alcohol extract (%) = Extract weight / Bone dry wood weight / x 100

III. Soluble matter in cold water

The residue from the alcohol extraction need be dried at 100°C and should be digested for 24 hours with 400 ml of cold water. It may be then filtered through a filtering crucible with fretted disk of coarse porosity G3 should be washed. The extract may be dried at 100°C for 10-12 hours and should be weighed.

Cold water extract (%) = Extract weight/Bone dry wood weight/x 100

IV. Soluble matter in 5 per cent NaOH solution

The residue from the soluble matter in cold water may be treated with 100 ml. of 5 per cent by weight NaOH solution for 24 hours and the solution should be filtered through the same filtering crucible with fretted disk of coarse porosity G3. The residue need be washed with 100 ml of 10 per cent by vol. acetic acid solution and should be distilled with H_2O. The residue at neutral reaction of the filtrate may be dried at 100°C for 10 to 12 hours and may be weighed

Alkali extract (%) = Extract weight / Bone dry wood weight / x 100

V. Cross-bevan-cellulose

Two grams of dry material, which should undergone the 4 extractions (1 + 4) need be transferred to the filtering crucible with fretted disk of coarse porosity G3. The filtering crucible may be put on vacuum flask with proper ice cooling container.

It need be washed with warm distilled water, and after having put the ice into the container, chlorine gas flow under slight vacuum should be passed through the filtering crucible for 5 minutes (velocity of the flow : 2 bubbles per second). Then the sample need be washed 2 to 3 times with a 1 per cent by volume SO_2 solution. The vacuum may be then disconnected and the fretted crucible filled up with 1 per cent by volume of soda solution (the material changes colour to brown). It should be digested with soda during 5 minutes. The vacuum should be connected and the chlorine flows again through the filter. This double treatment may be repeated until the material contacting the soda remains white. The solid matter may be then dried and should be weighed. Pentosans may be determined on the residue.

Wood theroetic weight = Wood weight after the four above mentioned extractions / 100 x sum % of four extraction / X 100

Cross Bevan cellulose (%) = Cross Bevan residue weight / Wood theoretic weight / X100

VI. Lignin

From the above four extracts fractions one gram sample in each, fraction may be placed in four test-tubes and should be treated with 12 ml of concentrated HCl. Each test-tube should be closed with a two holed rubber stopper, having an inlet tube going down almost to the bottom and an outlet tube. Through the inlet tube a flow of HCl gas should be passed which may be supplied by a Kipp apparatus with NH_4Cl and $2H_2SO_2$. After this stage the test-tubes may be left closed 24 hours. The contents should be mixed with water and should be filtered off and may be washed thoroughly until the acid reaction of the filtrate should disappeared. Later each sample may be dried at 100°C for 8 ~ 10 hours and should be weighed.

$$\text{Lignin} = \frac{\text{Wood weight after the four extractions} \times 100}{\text{Wood theoretic weight}}$$

VII. Ash

It should be determined on 2 grams of wood.

$$\text{Ash \%} = \frac{\text{Ash weight} \times 100}{\frac{\text{\% dry content of wood} \times 2}{100}}$$

VIII. Moisture

It should be determined on 10 gram of wood

$$\text{Moisture \%} = \frac{\text{dry wood weight}}{\text{moist wood weight}} \times 100$$

5. DETERMINATION OF PENTOSANS

(a) Preparation of the sample

One gram of bone dry wood saw dust may be weighed and should be placed into the distilling flask. Hundred ml of 12 per cent HCl may be added through the proper funnel and should be brought to boiling. After having collected 30 ml of distillate, 30 ml of 12 per cent HCl should be added in the distilling flask and thus proceeding until 360 ml of distillate may collected, this - amount being certainly sufficient to have all the formed furfural should be passed into the distillate (generally, all the furfural may be contained in the first 300 ml of distillate; however until furfural is present, a drop of distillate

should give a pink colour when coming into contact on filter paper with a drop of aniline reagent). Forty ml of the phloroglucin solution need be added to the distillate, then the volume of the liquid should be make up to 400 ml with 12 per cent HCl. It may soon turns greenish black and may furfural phloroglucide precipitates. (Hydrochloric phloroglucin solution free from resorting may be prepared by dissolving 74 g phloroglucin in 12 per cent by volume HCl, then need be diluted to 10 litres with 12 per cent HCl. The possible presence of resorting may be tested as follows : a small quantity of phloroglucin need be dissolved in few drops of acetic anhydride and may be brought to boiling; at this moment few drops of concentrated sulphuric acid may be added : a violet colour may indicates the presence of resorting.

After 16 hours decanting it should be tested whether all furfural may be precipitated, by adding a drop of aniline; if pink colour obtained (presence of furfural) more phloroglucin need be added (Aniline prepared by adding acetic acid or hydrochloric acid drop by drop to a mixture of equal volumes of aniline and water until a clear solution need be obtained).

The precipitate need be filtered through a filtering crucible with fretted disk of coarse porosity 11 G3 (or 11 G4). Care should be taken that the filter may always filled with liquid. The precipitate need be washed with 150 ml of distilled water and should be dried in oven at 100 to 150°C for 6 hours and may be placed into a desiccator until it may cooled and then weighed.

(b) Calculation of the results

The content of pentosans in the sample may be calculated from the weight of furfural phloroglucide (a) on the basis of the following formula :

Furfural = (a + 0.0052 + 0.0020) x 0.5170

Pentoses = (a + 0.0052 + 0.0020) x 1.0170

Pentosans = (a + 0.0052 + 0.0020) x 0.8949

If phloroglucide weight is between 0.03 g and 0.30 g

Furfural = (a + 0.0052 + 0.0020) x 0.5185

Pentoses = (a + 0.0052 + 0.0020) x 1.0075

Pentosans = (a + 0.0052 + 0.0020) x 0.8866

Over 0.30 g

Furfural = (a + 0.0052 + 0.0020) x 0.5180

Pentoses = (a + 0.0052 + 0.0020) x 1.0026

Pentosans = (a + 0.0052 + 0.0020) x 0.8824

The content in percentage may be figured from the pentosans content in the sample, by the following formula :

Weight of furfural phloroglucide + 0.0072 x 100 x 0.8866

Pentosans (%) = Weight of bone dry wood

Note : The value of pentosans may also be expressed as content of furfural (furfural deriving from hydrolysis). In such a case the possible errors deriving from presence of methyl pentosans should be lowered.

6. PULP AND PAPER CHARACTERISTICS

To study the pulp and paper characteristics of bamboo, the screened chips (chips density (BD) 224.76 kg (m^3) should be collected from summer chipper. The collected chips should be pulped individually in the laboratory series digester. The digester should be heated with indirect steam. The digester may initially be heated to a temperature of 80°C and the oven-dried chips equivalent to 2000 g. need be charged with chemicals. The cooking should be done at two different H factor to get two values of kappa number. The H factor need be maintained at 1300. (The pulping of bamboo may be regulated by the H factor which may singly represents time and temperature. This concept may be useful and should be applied to get more (a) less the sample pulp quality inspite of variations due to unforeseen reasons in temperature (or) duration of cooking). The other cooking conditions need be maintained at 19% to 22% active alkali (as Na_2O), 25% sulphidity, 1 : 3 liquor to chip ratio and 90 min. to raise the temperature to 170°C.

After cooking, the chips should be discharged thoroughly, washed, disintegrated and than screened. The screened chips need be pressed to remove the excess water, shredded, weighed and should be sampled for determining moisture content. The screened rejects should also be oven-dried. The pulp yield, and screened pulp, kappa number should be determined. Physical strength properties need be studied in the unbleached pulp. The bleaching experiments should be carried out for the pulps using CEH sequence. (Chlorination, alkaline extraction, hypochlorite). The bleached pulp samples need be refined in a valley beater to different freeness values. The hand sheets should be made to determine the strength properties. The sheets need be conditioned at 23 + 1°C temperature and 50 + 1% relative humidity. The black liquor obtained in each case should be analyzed for total solids, inorganic, organic ratio, acid solubles, all sodium salts (Na_2O), free alkali, Swelling Volume Ratio (SVR), Calorific value and viscosity at different concentrations.

CHAPTER 13

COMPARATIVE STUDIES

1. CONVENTIONAL INVESTIGATIONS ON FOREST BIOMASS

The importance of forest productivity studies lies on accurate estimation of aerial and sub-aerial biomass. An approach to estimate the total dry matter production in the standing crop from easily measurable parameters will be advantageous for pulp industries since the oven-dry weight of the wood is a better indicator of pulp yield than volume. Above all, dry matter production provides information to examine the nutrient budget of an ecosystem which is important or rational management of forests. The term 'production' in general may be considered as the rate of net primary production of organic matter left after respiration but including all loses from litter fall, grazing etc. (Equnjobi, 1957).

Ovington (1962) distinguished "mean annual net productivity" by averaging the biomass over the age of the stand and the "current annual net productivity" which is the then current rate of organic matter production and is considered more useful in the estimation of biological productivity.

Comprehensive account on different aspects of biological productivity has been presented by Ovington (1962) and Kira and Shidei (1967). Besides, several comprehensive reviews have been published for world forests (Rodin and Bezilevich, 1968; Art and Marks, 1971) and tropical forests (Golley and Leith, 1972; Ovington,

1972). Net primary productivity of tropical forests average 25.3 t/ha/year, the gross primary production being 80 t/ha/year. Tropical climate is conductive for biomass production (Golley and Leith, 1972). Working on the forests of Thailand, Ogawa *et al.*, (1961), concluded that biomass of an ecosystem (or) an individual species tends to change with time and place. In a well established forest, standing biomass was found to range between 200-350 t/ha irrespective of climate zones.

Alexon (1980) found that structure and dynamic of *Calluna vulgaris* on the sand dunes of South Sweden. Age, structure, biomass and productivity of *Calluna vulgaris* occurred through successive embedding and frequent adventitious rooting of trailing stems and no marked difference in structure inspite of age of the heaths. Anand (1986) determined the biomass of standing crop, turn over value and annual increment of *Hydrilla verticillata* and found that higher values of biomass production were recorded in winter and lowest during summer period and 56 to 87 per cent of biomass was being replaced by each season.

Working on Swiss Woodlands, with ages from 13 to 90 years, Burger (1953) obtained variation in fresh weight of different biomass ractions (expressed x 10-3 kg/ha). Thus leaf biomass ranged from 36 (Scots pine) to 61 (for Norway spruce). Dry weights were observed to be about 40 per cent of fresh weights. Metz (1954) comparing hardwood and pine stands in South Carolina calculated the dry weight of organic matter and expressed as X 10 kg/ha, which ranged from 6 to 12 in hard wood stand, from 13 to 18 in mixed hard wood and pine stands, and range from 17 to 23 in pine stands. Will (1964) determined average annual biomass accretion in the standing trees (excluding roots) to be 12.3 X 10-3 kg/ha for 12 years old Monetery Pine stands in New Zealand.

Satoo (1968) has discussed production relations covering 67 woodlands of Pinus densiflora in eastern Japan and observed that branch and root biomass increased with age of the woodland although the effect of stand density on branch biomass was large. However, no relation could be established by these studies between leaf biomass and age of the woodland upto 46 years. Mixed deciduous forest in Belgium was found to have a root biomass of 13 per cent of the aerial biomass and the productivity of the trunk was estimated to be 4.48 t/ha (Duvigneaud and Denaeyer De Smet, 1968). The distribution of organic matter in a mixed deciduous woodland, dominated by *Querus robur, Tilia cordata, Corylus avellana* and *Anemona nemoirosa* was compared and Anderson (1970) found total plant biomass of 240 t/ha and 39 t/ha as above and underground value respectively, by using

dimension analysis applying allometric equations. Huzumi *et al.*, (1967) studied production ecology of tropical rain forests in South-Western Cambodia pertaining to Health forests and Melaleuca Swamp forests. Comparing biomass of evergreen seasonal forests of Checko in South-Western Cambodia with the obtained in moist tropical forests of Thailand and Coted' Ivoire the forests of Checko was found to have a biomass equivalent to other rain forests. Further they have concluded that the Checko forests are characterized by a specific DBH (diameter at breast height), tree height curve, a small leaf area index and a high value of leaf area/leaf weight ratio.

Whittaker *et al.*, (1963) while working on three tree species at Oak Ridge, Tennesse, inferred that concentration of biomass in woody structures increased from small shrubs to medium sized trees. Discussion causative factors, Ogawa *et al.*, (1965) observed that total plant biomass of a forest increases with increase in moisture of the environment. Fluctuation of the biomass on small area was found by them to be much greater for woody organs rather than for leaves. Whittakar's (1966) biomass estimates on Cove forests show correlations with environment. Cove forest biomass worked out to be larger than any other reported from wither temperate (or) tropical forests. At any elevation, biomass was observed to decreased from mesic to xeric sites. In most forests tree biomass greatly over shadows that of all other plants.

Westlake (1963) has worked out the productivity levels of temperate deciduous and coniferous forests to be 12 and 28 t/ha/year. The figure quoted by these authors for some other plant species are birch and elder which are 8.9 and 16 dt/ha/year respectively. Ovington (1963) from their comparative studies on the prairie, Savanna oak wood and maize field ecosystems in the Central Minnesota have concluded that the amount of organic matter present in a woodland is not constant, but it varies in regular manner during a year, as new growth proceeds and the old woodlands contain a great mass of organic matter but their biomass tends to be relatively constant over the years. It has further been shown that different types of organic matter differ greatly from area to area and that the weights of living vegetation in Savanna and Oak wood exceed that of prairie and maize field. Studying the biomass production of local pine plantation during the growing seasons of 1971-72, Ralston (1973) observed that the total annual growth was 18t/ha during 1971 and 12 t/ha during 1972.

2. GROWTH AND YIELD IN ENERGY PLANTATION

Several studies have been done particularly from the point of duel and pulp yield in certain hardwood species. Ripe (1973), Howlett

and Gamache (1977) have reviewed the work on short rotation forestry. The need for high demand of wood, has necessitated the short rotation forestry also called energy plantations. Since, the normal forest yield range from 3 to 8 dt/ha/year, over a period of 30 to 80 years, short rotation forestry can achieve an yield of 12 to 25 dt/ha/year over 4 to 10 year cycle (Gibson, 1978) with the high cost of land, growing trees for 40 to 60 years has become unduly expensive (Ripe, 1973). New concept and new approaches need to be evolved for economic production of certain forest materials. This can be achieved by short rotation forestry also termed as energy plantations, which is being perused by several workers. (Harrick and Brown, 1967; Einsphar and Benson, 1968; Steinbek *et al.*, 1973; Schreiner, 1970, Saucier *et al.*, 1972; Young, 1972 and Schmidt and De Bell, 1973). The various advantages of such energy plantations have been outlined (Ripe 1973). Bower Sox and Ward (1976) reported an yield of 19.7 dt/ha/year with 22000 trees of populous clone over the period of 7 years. Other workers for different populous clones report a density of trees from 10,000 to 1,00,000 per hectare. However, the yield rarely exçeed 20 dt/ha/year (Cannel and Smith, 1980).

Akachuku (1981) have reported that *Gmelina arborea* reaches the maximum value, from over 20 dt/ha to over 30 dt/ha in 4th, 5th and 6th year. The accumulative growth was around 108 to 161 dt/ha. He further states that growth rate and yield of forest plantations should be expressed preferably as weight rather than as volume, since weight gives better indication of the proportion of cells-wall than volume. Ek and Dawson (1976 a,b) suggested the possibilities of biomass production of over 40 dt/ha/year based on small plot trials. Cannel and Smith (1980) reviewing on short rotation of hard woods in temperate region conclude that the mean annual increments are not very much significantly higher when compared to those obtained from medium term hardwood plantation in a good site. Madgwich *et al.*, (1981) reported 20 dt/ha/year with 6470 stems/ha. Pearce (1983) working on the production model of various species grown under short spacing coppice system using mainly Populus, Alnus and Eucalyptus species concluded that it is possible to achieve more than 20 dt/ha/year in a 4 to 8 year cycle. Frederick *et al.*, (1983) reported 30 dt/ha/year yield for *Eucalyptus regnans* at the age of 10 years.

They further state that, it is possible to double the yield with appropriate management practices. In *Acacia dealbata* 181 dry tonnes have been obtained at the age of 8 years, which worked out to be 22.6 dt/ha/year.

In view of the possibilities of obtaining higher yields, studies on energy plantations are now being conducted with specific prospects of

species and area rather than a general concept. Many species such as sweet gum, cotton wood, red elder, popular have been or being tried. Of the 500 Eucalyptus species, over 50 of them are believed to be good for energy plantations (Elisco and Mariani 1978). They have further reported for Eucalyptus an average yield of 16, 10, and 8 dt/year for India, Italy and Australia respectively 13 years old. *Eucalyptus regnans* at Forest Research Institute, Roturua yielded a total standing volume of 307 m-3/ha, the increment being 23.6 m-3 per ha/per year (Wilcox and Thulin 1979). Even at the conventional spacings at the age of 5 years was reported to be 145 m-3/ha and 353 m-3/ha at age of 10 years (Pool, 1979). Mitchell and Mathews (1983) initiated experiments on energy forestry using *Almus glutinosa, Betula pubescence, Acer pseudoplatanus, Larix xeurolopis, Pinus sylvestris, P. nigra, Pseudotsuga menziesii, Tsuga heterophylla* and *Picea sitchensis* each with 10,000 plants/ha. They suggested the possibility to obtain high yield and survival rate. In order to obtain high yields water, either as rainfall or as irrigation is essential. Fraser *et al.*, (1976) claim that minimum 500 mm of rainfall is essentail for 17 dt/ha/year, which was also substantiated by Gurumrti *et al.*, (1983). However 600 mm (White and Plaskett 1981) was reported to be essential for energy practices under rainfed conditions. These requirements thus, impose geographical limits or may imply irrigation.

Another factor that is physiologically more useful particularly in young plantation is the growth analysis which can also be regarded as useful tool in analyzing net photosynthetic production by plants, which in photosynthetic terminology is net assimilation rate. Growth analysis in plants has extensively been worked out by British School (Blackman 1968) and with slight modifications by Leith an Whittaker (1975). Seshadri *et al.* (1978) obtained an yield of 200 dt/ha in four years cycle using *Casuarina equisetifolia*, both in the West and East Coasts. Kimothi *et al.*, (1983) seven different species grown under semi-arid non-rigated conditions reported that *Dalbergia sissoo* and *Prosopis juliflora* produced a maximum total biomass of 114 dt/ha within three years. Biomass inventories of Indian forests were mostly carried out and reviewed by Kaul and Co-workers (1983) at Forest Research Institute and Colleges, Dehra Dun, besides Pandeya, *et al.*, 1974, Singh and Sharma, 1975, Agarwal 1972 and Misra 1969).

3. GROWTH AND YIELD IN MONOCULTURES

A number of the investigation on monocultures of Eucalyptus (George 1977; Negi *et al.*, 1984; Gupta and Raturi 1984), *Pinus patula* (George *et al.*, 1982), Malhotra *et al.*, (1985), Singh (1982), Bhartari

(1986). Holland (1969) estimated the aerial biomass and its annual increment in two forests of Malle vegetation which differed in species composition in age. The biomass of standing crop in *Acer spicatum* which ranged from 0.74 t/ha at one year to 40.45 tons/ha at 26 years of age. In 25 years old *Abies balsamea* the standing crop was 58.55 t/ha. Annual increments in organic matter were 0.81 t/ha/year in stem wood, 0.51 t/ha/year in branches, 0.71 t/ha/year in stem bark. The annual weight increment was found to be constant from 8 years to 26 years age in *Acer spicatum* while in *A. balsamea* it was initially very low but increased at 25 years of age (Post, 1970). The biomass of *Shorea robusta* (Bandhu, 1970), *Tectona grandis* (Vyas *et al.*, 1976, Vyas *et al.*, 1976, Ramprasad and Misra, 1884), five other species (Pandeya *et al.*, 1967, 1970, 1974) were determined in Gujarat forests. Kandaya (1974) carried out organic matter production in above and below ground parts of some tree species Negi *et al.*, (1984) investigated the distribution of organic matter in *Eucalyptus globulus* plantations of Tamil Nadu, which ranged from 38 tonnes (5 years) to 220 tonnes (16 years) per ha with 85 to 88 per cent being above ground and 15 to 12 per cent by the roots. Maslekar (1984) investigation showed that in irrigated and rainfed plantation the average biomass excluding roots and stumps, was 29.42 and 14.94 kg per tree respectively. According to Rai (1984), the average standing biomass of plants in western ghats of Karnataka, 458.204 t/ha while shrub and herb-layer ranged from 5.90 and 0.288 t/ha respectively. Above ground biomass estimates in some tropical rain forests of the world have been given by Greenland and Kowal (1960), Kira *et al.*, (1964), Hozumi *et al.*, (1967), Odum and Pigeon (1970); Jordan (1971); Anonymous (1975); Whitemore (1975); Edward and Grubb (1977); Enright (1979) and Tanner (1980). The range of reported above ground biomass for those forests is from 229 to 505 t/ha and the average for 11 sites is 327/45 t/ha.

Studies on various aspect of *Eucalyptus* species viz. the survival and growth rate, timber and fuel yield etc. have been reported by various workers (Kaul *et al.*, 1983; Ramprasad *et al.*, 1984 and Ganguli 1961; Ghore and Shedha 1971; Chaturvedi 1983a, b), Singh (1982) published an account of net primary productivity and productive structure of *Eucalyptus tereticornis* plantations grown in Gangetic plain. Biomass studies in respect of equally important exotic species Populars was reported by Kaul *et al.*, (1983). Ram Prasad *et al.*, (1984) studied biomass production in relation to various plant parameters of 5 and 15 year old *E. camaldulensis* and reported, the mean annual productivity of 15.92 t/ha/year in 5 year old plants and 6.03 t/ha/year in 5 year old plants. Gurumurti *et al.*, (1984) reported the biomass production in energy plantations of *Prosopis juliflora*.

The distribution of organic matter in different tree components of 3, 5, 9, 11 and 13 years old plantations of *Pinus patula* has been discussed by Sharma and Srivastava (1984). The total biomass ranges from 7 tonnes (3 years) to 194 tonnes (9 years) per ha with 82 to 87 per cent being contributed by the above ground parts and 13 to 18 per cent by root. The distribution of nutrient in *Eucalyptus globulus* plantations of Tamil Nadu was studied by Negi and Sharma (1984). According to them as a result of harvesting, to bole (59 per cent of total biomass) there will be a removal of nearly 44 per cent (N and P), 29 per cent (K), 7 per cent (Ca) and 24 per cent (Mg) at 7 years. The same plantation when harvested after 16 years a bole biomass of 74.3 per cent will cause a removal of 55 per cent of N, 65 per cent of P 22 per cent of K, 13 per cent of Ca, and 27 per cent of Mg.

Analogous to the biomass studies on *Eucalyptus, Pinus* and other energy plantation crops, attention is focussed on bamboo and research on bamboo has increased rapidly especially in recent years. The momentum, especially in Asian countries, were strengthened by the creation of International Union of Forestry Research Organization (IUFRO) Project Group on Bamboo in 1976, at the Congress in Olso, followed by an International Development Research Centre (IDRC). The Bamboo management, culm growth and clump expansion behaviour of different bamboo species from South East Asia were reported. *Bambusa arundinaceae* (Kondas *et al.* 1973, Lakshmana 1990, Swamy Rao *et al.*, 1991, Shanmughavel and Francis 1993), *Dendrocalamus strictus* (Lovegrove 1990, Dubey, 1991), *D. longispathus* (Hasan 1975, 1979) *D. hamiltonii* (Rao and Ramakrishnan 1988, 1990), *Gigantochloa levis, G. ligulata, G. scortechnii* (Othman, 1992).

However, detailed study on the growth parameter, biomass production nutrient cycle of bamboos are very little when compared to other species of *Eucalyptus, Casuarina, Pinus, Prosopis* etc.

Comparative performance of *Bambusa balcooa, Dendrocalamus strictus* (Tewari *et al.*, 1994), the highest specific gravity and bending strength of *Bambusa bambos* (Kabir *et al.*, 1993), culm production and clumps girth expansion (Banik 1988, Sattar *et al.*, 1990), *D. structys* afforestation trial (Prasad and Dhuria, 1989) in social forestry (Islam and Kanwar 1987) was investigated. Cultivation of bamboo with economic success in denuded soil (Gupta 1979) and utilization of waste lands for bamboo plantations under intensive management to meet the shortfall in bamboo resources (Adkoli, 1990) are in vogue.

4. NUTRIENT INVESTIGATIONS IN BIOMASS PRODUCTION SYSTEMS

The importance of nutrient levels in biomass production system is paramount. The significant of nutrient management has been well recognized from early times which has become highly relevant with the advent of commercial forestry, wherein there is continuous increase in production and removal of biomass out of the system. Such impact of intensive harvesting need extensive understanding of not only nutrient distribution in different components of plants, but also need to be studied in terms of cycling through the processes such as geochemical, biochemical and biogeochemical mechanisms. The relative contribution of these process is generally studied by examining the soil litter system, which include the mineralization of organic product for growth, uptake of nutrients, contribution of mucorrhiza and supply of nutrients from available sources deep in the soils. Many of the inorganic nutrients circulate either within the plants through the litter via forest floor. This circulation does not form a close system to ecosystem changes since chemical elements are added and removed in different ways (Ovington 1962).

The accumulation of nutrient element within the organic matter of forest ecosystem growing on fertile soils, tends to be greater than those growing in poor soil (Ovington, 1962). The nutrients namely Na, K, Ca, P, Mg and N of many forest ecosystems of the world are the highest when plantation are fully leafy. The largest amount of accumulation and dynamics of ash chemical elements are found in the leaves, the smallest being in trunks and branches, the levels in root being intermediate (Rodin and Bazilevich, 1967, 1968). Investigations on nutrient cycling in temperature forests (Bray and Gorham, 1964; Gessel and Turner, 1974; Kikuzaw,a 1978) and tropical forests (Nye, 1961, Odum, 1970, Golley *et al.*, 1975 and Edwards and Grubb, 1982) are in line with biomass components of different tree species.

A literature survey though indicated that much of the work in nutrient content and nutrient dynamics of natural forests and plantation systems have emanated from out side country. Considerable work has been done in India mostly at Forest Research Institute in Indian Forests (Kaul *et al.*, 1973, 1979, 1981, 1982 and 1983) as well as in plantations, *Eucalyptus hybrid* (George, 1977, 1986), *Acacia mearnsii* George and Varghese (1990a,b) *Shorea robusta* (Kaul *et al.*, 1979) *Eucalyptus globulus* Negi *et al.*, (1984), Negi and Sharma (1984) *Eucalyptus camaldulensis* Prasad *et al.*, (1984) Kushalappa (1987) *Eucalyptus grandis* Tandon *et al.* (1988) *Acacia tortilis A. nilotica, L. leucocephala* Pandey *et al.*, 1989, Pandey

et al., 1967, 1970, *Pinus kasiya* Das and Ramakrishnan (1987) *Dendrocalamus hamiltonnii* Rao and Ramakrishnan (1989, 1987), Kimothi (1984) Saxena and Ramakrishnan (1984), Singh and Ramakrishnan (1982) *D. hamiltonii* (Toky and Ramakrishnan 1982, 1983a, 1983b) Joshi *et al.*, (1991) and in other countries; Attiwill (1981) Baker and Attiwill (1981), Dyer (1967) Greenland and Kowal (1960) Hingston *et al.*, (1979), Klimmina and Krunlik (1976) Madgwick *et al.* (1981) Richards (1981) Frederick *et al.*, (1979), Switcher *et al.* (1966) Vanlear *et al.*, (1984), Locksby and Adams (1986) Young and Carpenter (1967) Malkomen (1973) Turner (1981). Abrahamson and Caswell .(1982); Hocking (1984) (*Ixia flexucha*) Switzer and Nelson (1972), *Pinus taeda* Woodwell *et al.*, (1975) Egunjobi and Bada (1979), *Pinus caribaea*, Grove and Malajuczuk 1985 *Eucalyptus diversicolor*, Kadeba (1986) *Pinus caribaea, Gmelina plantation,* Nwobushi (1985), *Pinus carbaea* Kabeba (1991), *Terminalia superba* (Aluko 1993) *Pinus radiata* Madgwick *et al.*, (1977), Foster and Morrison (1979) Viro (1967). Kimmins and Krumilik (1976).

Extensive investigation on nutrient budgeting of *Eucalyptus hybrid* plantations revealed the depletion of nutrients at the time of harvest in Eucalyptus plantations (George, 1977). At this situation either application of direct fertilizer or leaving certain components like bark in the field at the time of harvesting, nutrient depletion may averted. With regard to concept of energy plantations the management of nutrient assumes great importance. Much of the work on same what similar has been done by Young and Co-workers (1980) at Universtiy of Maine, Orono, U.S.A. Dyer (1967) and Ribe (1973) advocate complete tree utilization concept with appropriate nutrient management.

5. LITTER PRODUCTION AND NUTRIENT RETURN

It has been recently realised that establishment of the plantations on waste lands is imperative to neutralize the rapidly widening mismatch between demand and supply of wood resources (Swaminathan 1980) and maintenance of an agie agro-ecological system. Besides tree plantations are known to result many beneficient interactions with the surroudings. Thus the soil, the important natural resource, is greatly influenced by the production of litter and nutrient cycling. Studies on the litter aspects are investigated in greater length by Ramakrishnan and Singh (1983) and Khiewtam and Ramakrishnan 1993. Litter enriches the soil with organic matter (Gill and Abrol, 1986 and Hoyle, 1973) and essential nutrients (Gill, 1985). Its accumulation on the surface also check

weeds and protects the soil from the erosive impact of rain and reduces surface water run-off (Dominski, 1971, and Bell, 1973). Poor soil organic matter status in the tropical and sub-tropical regions further makes the litter production characteristics of tree plantation (Gill *et al.*, 1987).

Studies on litter production (Bray and Gorham, 1964) and decomposition and surface fine root mat (Stark and Jordan, 1977; Stark and Spratt, 1977; Harris *et al.*, 1980; Singh and Smith, 1981) are important aspects of the functional attributes of ecosystems, particularly because of their implication on nutrient cycling. Studies on litter dynamics from the humid tropical forests (Toky and Ramakrishnan, 1983; Proctor, 1984) are particularly important because the rates of litter production and decomposition are very high with consequent rapid cycling of nutrients through this pathway. Similarly, many tropical rain forests have extensive root mats developed over the nutrient root systems (Ramakrishnan and Singh, 1983; Ramakrishnan, 1984) aid in nutrient conservation through direct transfer from decomposing litter to roots (Stark and Jordon, 1977). Fine roots located in surface soil layers are also important in forest nutrient cycling (Medina and Cuewas, 1989). Information on the above lines in tropical forests (Odum 1970; Golley *et al.*, 1975; Edward and Grubb, 1982) and temperature (Vitousek and Sanford (1984) Vitousek (1982) zones of the world (Bray and Gorham, 1964; Gessel and Turner, 1974; Kikuzawa, 1978) are available, which reveals the rate of cycling of nutrients and interaction between the soil and vegetation compartments.

While there are many references to quote on nutrient cycling in natural forests and plantations, from outside the country (Duvigneaud and Smet, 1970; Westmann, 1978; Walls and Jorgenson, 1976; Turner and Lambert, 1983; Cromer *et al.*, 1976; Roger and Westman, 1979; Lousier and Parkinson, 1976 and Aluko 1993; Hopmans *et al.*, 1993) Kadeba (1991).

Grove and Malajuzuk (1985) Jokala *et al.*, (1981) Jorgenson and Wells, 1986; Nye 1961, Forest and Ovington, 1970; Bradstock, 1981; Egunjobi and Bada, 1979; Kadeba and Aduayi, 1985, Nwohboshi, 1985; Kadeba 1986, Lundgren, 1978) and in India (Sethi *et al.*, 1963; George 1977, 1985, 1986), George and Varghese 1990a, 1991, Kaul *et al.*, 1979, 1981 and 1983; Sharma *et al.*, 1985; Bhartari, 1986; Bray and Gorham, 1964; Singh, 1968, 1969; Srivastava *et al.*, 1972; Venkataramanan *et al.*, 1983; Singh *et al.*, 1984; Negi and Sharma, 1984; Singh and Sharma, 1975; Tandon *et al.*, 1988; Kushalappa, 1987; Pandey *et al.* 1989). The results of the studies, show the

importance of selective harvest of biomass components over a complete tree with reference to nutrients uptake and cycling.

Annual litter production in deciduous and evergreen forests of India have been reported for Sal (*Shorea robusta*), Teak (*Tectona grandis*) Chir (*Pinus roxburghii*); *Picea smithiana, Abies pindrow* and *Pinus wallichiana* (Puri, 1953; Upadhyaya, 1955; Singh, 1968, 1969; Seth *et al.*, 1963; Subba Rao *et al.*, 1972; Garg and Vyas, 1971; Singh and Ramakrishnan 1982; Singh *et al.*, 1984; Anurag and Srivastava, 1986).

The litter decomposition and nutrient release was investigated by Gessel and Turner, 1974; Ewell, 1976, Lousier and Parkinson, 1976; Edward, 1977; Pandey and Singh, 1981; Gupta and Singh, 1981; Deka and Mishra, 1982; Singh and Joshi, 1982; Briggs and Maher, 1983; Das and Ramakrishnan, 1985; Hopmans *et al.*, 1993; Pandey, 1986; Annadurai *et al.*, 1988 Baghuguna *et al.*, 1990.

In north-eastern hill areas of India slash and burn agriculture (jhum) is the common land use practice (Rao and Ramakrishnan, 1987, 1988a, 1988b; Saxena and Ramakrishann, 1984, Singh and Ramakrishnan, 1982; observed litter accumulation under bamboos forests. The jhum cycle has resulted in a wide variety of environmental problems related to soil fertility (Ramakrishnan *et al.*, 1981) nutrient losses (Toky and Ramakrishnan, 1983, 1983a, 1983b), Joshi *et al.*, (1991) reported the nutrient dynamics of a lower Siwalik bamboo (*Dendrocalamus strictus*) forests in the Central Himalaya.

6. PROXIMATE CHEMICAL ANALYSIS

(a) Cellulose

Forest Research Institute, (F.R.I.) Dehra Dun pioneered the researches on the exploitation of the suitability of bamboo as a raw material for commerical production of various varieties of paper. The history of these researches dates back to 1909, when Sir Pearson, the Forest Economist, made on extensive survey on the availability of bamboo in India and Sir Raitt Paper Technologist initiated studies on evolving an efficient and economic process for the preparation of easy bleaching. Since then the proximate chemical composition of *Bambusa bambos, B. polymorpha, B. tulda, Dendrocalamus strictus, D. longispathus, D. hamiltonii, Melocanna baccifera* and *Schizostachys dulloa* were tested for pulp and paper (Bhargawa, 1945), whose proximate chemical composition varied from locality and also with flowering. Results on nature, chemical composition of cellulose from *Dendrocalamus strictus* (Wilson, 1965; Negi, 1969, 1970; Singh *et al.*, 1974, Chandra and Guha, 1979) *Bambusa*

arundinacea (Guha and Pant, 1967), *Melocanna baccifera* (Dhawan and Singh, 1982), *Dendrocalamus strictus, Bambusa arundinacea* and *Bambusa tulda, Melocanna bambusoides* (Maheswari, 1982; Maheswari and Satpathy, 1984, 1988); *Dendrocalamus strictus, Bambusa bambos* (Escalano, 1973; Khoo and Peh, 1982; Monsalud and Nicolas (1958), *Bambusa blumeana, Schizostachyum zollingeri, Gigantochloa scortechnii* and *Bambusa vulgaris* (Azmy Mohamed *et al.* 1991) were reported so far revealed that cellulose content of above studied species ranges from 57.56 per cent to 77.36 per cent.

(b) Lignin

The chemistry of various bamboo lignin has been investigated in detail (Singh 1975; Pant *et al.*, 1975; Bist *et al.*, 1974; 1975; Ghose and Negi, 1981, Maheswari, 1982; Maheswari and Satpathy, 1984, 1988; Jamaluddin *et al.*, 1993; Bose *et al.*, 1988; Singh and Guha, 1976; Khoo Peh, 1982; Pant *et al.*, 1975; Monsalud and Nicolas, 1958). It reveals that lignin content varied from 18.80 percent to 30.09 per cent in all species.

(c) Fibre

The fibre length of bamboo varies from species to species, in some species from bottom to top and in others within internodal length and the pattern of variation is also not same in different species (Pattanath, 1972). Variation are also reported with the well in bamboo (Liese and Grosser, 1972). Variation in fibre length of various bamboo species evaluated for pulp and paper have been reported by Singh *et al.*, 1976). The tensile strength and tearing resistance of paper are correlated with fibre dimensions and length (Siddique and Choudhury, 1985). The fibre of 1-3 year old *Gigantochloa scortechnii* varies from 3.0 to 3.7 mm (Kasim *et al.*, 1993). The inherent long fibres of bamboo provide high tearing resistance (Escalano and Semano, 1970). The fibre length of *Bambusa vulgaris, Gigantochloa scortechnii* generally increases with age but in *Bambusa blumeana* decreases (Latif and Mohd. 1992).

Fibre length is an important criterion in identifying the fitness of the wood for pulping as it has direct correlation with the tearing strength of the paper (Bublitz, 1980). Fibre length also influences drainage capacity of the pulp (Subramaniam, 1987), besides the physical and mechanical properties which inturn affect the workability (Paramasivam and Liese, 1976). The bamboo fibre qualities attain the maximum within first 12 months (Razzaque *et al.*, 1981).

The yield of sugar was highest in the case of *Dendrocalamus strictus*, whereas pentosans and methoxyl content were highest in case of *D. hamiltonii*, whereas *Melocanna baccifera* had the lowest yield of sugar, pentosans, methoxyl content (Dhawan and Singh, 1982). With an increase in age, holocellulose, lignin and ash content, also increase (Maheshwari and Satpathy, 1984). Generally the bamboo species with lower lignin content contained higher cold and hot water solubles, but these with higher holocellulose had lower cold and hot water solubles. Bamboos having higher cellulose and lower lignin content are very suitable for pulp and paper (Chen *et al.*, 1985; Escalono, 1973). Bamboos have similar chemical properties as most tropical hardwoods (Khoo and Pen, 1982). The chemical composition varies according to the individual characteristics of the species, age, position of culm, its geographical distribution (Liese, 1989; Negi, 1970) reported on the effect of pentosan content in pulp in beating characteristics indicated that as the pentosan content in pulp increased, the beating time was progressively reduced. Solubility in 1 per cent NaOH and cold water increased with culm height. Similar trend of variation was also reported by Jamaluddin and Ashore (1991), Maheswari and Satpathy, 1984, Jamaluddin and Latif, 1993).

Immature bamboo contain less lignin (Guha and Negi, 1989) and thus need less drastic conditions for dehumidification (Bose *et al.*, 1988). No appreciable change in chemical composition, fibre dimension, pulp yield and physical strength properties of pulp could be monitored with increasing age (Razzaque *et al.*, 1981).

In comparison with chemical characteristics of *Bambusa blumeana, B. vulgaris, Gigantochloa scortechnii* and *Bambusa bambos* showed several trends in the distribution of the chemical components studied (Mohd and Mohamed, 1991) *B. bambos, Schizostachyum zollingeri* contained higher holocellulose and lignin, but less cold and hot water solubles. In case of older bambos the per cent yield of holocellulose are lower (Youdi *et al.* 1985).

7. PULP AND PAPER CHARACTERISTICS

Raitt (1913) evolved a process for preparation of easy bleaching of pulp from bamboo, and its suitability for pulp and paper manufacture. Crushing of bamboos prior to chipping improved pulpability (Bhargawa, 1945). The pulping results of *Dendrocalamus strictus, D. hamiltonii, D. longispathus, Melocanna baccifera, Bambusa bambos, B. polymorpha, B. tulda, Ochlandra travancorica, Gigantochloa rostrata* and *Schizostachyum dulloa* were conducted at FRI, Dehra Dun in 1923, Pulp from various species of bamboo may obtained by 14-15 per cent active alkali at 25 percent sulphidity, to

produce chemical pulp (40 per cent yield) suitable for making writing and printing papers. The bleach demand was 12-15 per cent for attaining 75-78 per cent brightness using CEH sequence (Bhola, 1976; Negi, 1970; Guha *et al.*, 1975; Bhandari, 1981; Shah *et al.*, 1991). High quality unbleached sulfate drive from *Ochlandra travancorica* and *O. rheedi* (Singh *et al.*, 1977), *Phyllastachys bambusoides* (Guha and Parameswaran, 1966).

Bamboo pulps bleached with bleaching powder were found to change in colour and turn brownish on storage. Papers made from such pulps also found to deteriorate in shade on storage and thus depreciate in value and quality. Hence Singh *et al.*, (1970) reported that adoption of two stage system of bleaching which gave satisfactory results, Singh *et al.*, (1968) showed that bleached sulfate pulp can be produced by pulping bamboo along with mixed tropical hardwoods in equal ratio. Studies on bleaching of sulfate pulp prepared from *Dendrocalamus strictus* (Jain et al., 1976 and Rao et al., 1988) reveal the changes in pulp properties throughout the bleaching sequence CEH (Chlorination, alkaline extraction and hypochlorite). Singh *et al.* (1987) found that sulfate pulps from *Ochlandra travancorica* and *O. Scriptoria* could be bleached with CEH sequence to 76 per cent brightness applying 7.7-8.2 per cent total chlorine to oven dry pulps. Production of groundwork pulp from *Bambusa nutans, Dendrocalamus strictus* and *Bambusa tulda* was studied by Bhandari (1981), *Dendrocalamus strictus* (Pravin, 1987 and Sahoo, 1992). The role of bamboo in the manufacture of rayon grade pulp from ground work pulp and chemical and morphological characteristics of major species used for paper making was reported (Singh and Guha, 1981 and Singh *et al.*, 1988), Mohammed *et al.*, 1991; Jamaluddin (1993) reported that kraft pulp yield of *Bambusa vulgaris* (45-53) compares well with 50-52 per cent by Bhargawa and Jauhari (1971), 42-48 per cent of the sulfate process (Chao and Pan, 1972; Guha *et al.*, 1975). The results further indicated that all the properties studied (except for pulp freeness and tearing resistance) increase with beating time. The increase in breaking strength could be attributed to the increase in fibrillation which leads to increase in fibre bending (Casey, 1980). Tearing resistance on the other hand depends entirely on the fibre length (Wangaard and Woodson, 1973; Singh *et al.*, 1989).

Physical strength properties of the pulp are independent of age (Bose *et al.*, 1988, Razzaque *et al.*, 1981). The factors such as age, position of culm, climate etc. effect the strength properties of pulp (Kabir *et al.*, 1993; Soeprayit *et al.*, 1988; Sattar *et al.*, 1990, Gnanaharan *et al.*, 1991). The rate of dehumidification increased with

an increase in active alkali change (Mohamed *et al.*, 1992). Total pulp yield also increases with increase in the age of the culm (Maheswari and Satpathy, 1984). Bleaching of pulps of *Dendrocalamus strictus* with cold caustic soda improve the brightness of the pulp (Bhat *et al.*, 1972) Good tear, burst, tensile and folding endurance value are requisites of a good paper. These values vary with the fibre length and diameter as well as ratio of these two (Razzaque *et al.*, 1981). Soda thermomechanical (SSTM) pulp from bamboo (*D. Strictus*) were prepared from pre impregnated chips using (10 per cent) solution of sodium hydroxide and a mixture of sodium hydroxide and sodium sulfate (in the ratio of 4:1) (Singh *et al.*, 1987) showed good results.

For the production of bleached grade sulfate pulp is normally carried out by using chlorine and calcium hypochlorite as bleaching agents with intervening caustic soda extractions. However, bamboo mechanical pulp-semi chemical high yield pulps have limited use due to poor strength and bleachability. The process developed at FRI, Dehra Dun, to activate Soda Thermo mechanical (STM) pulp of bamboo have yielded excellent results with respect to improvement in bleachability and strength properties.

The present state of knowledge of bamboo plantations ecosystems amply demonstrates the lack of studies on productivity, nutrient cycling and pulp and paper characteristics of *Bambusa bambos* plantations in India. The present study gives an insight into the biomass, nutrient cycling, pulp and paper characteristics of plantation bamboo.

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அணிந்துரை

வனப்பகுதியிலிருந்து கிடைக்கும் மிக முக்கிய பொருள் மூங்கில். இயற்கையாக வனப்பகுதிகளில் 75 பேரினங்களைச் சார்ந்த 1250 சிற்றினங்கள் பரவியுள்ளன என்பது தெரிய வந்துள்ளது. நமது வனப்பகுதியில் 10.03 மில்லியன் ஹெக்டேரில் அதாவது மொத்த வனப்பகுதியில் 12.8 சதவீதம் பரவியுள்ளது. நாளுக்கு நாள் பெருகிவரும் மக்கள் தொகையின் மிக அதிகமான உபயோகத்தினாலும், வனப்பகுதிகளில் ஏற்படும் அழிவினாலும் காகித ஆலைகளில் மிக முக்கிய பொருளாக இருப்பதாலும், யானைகளின் முக்கிய விருப்பமான உணவாக இருப்பதாலும் தற்போது இயற்கையாக வனங்களில் காணப்படும் மூங்கில் பெருமளவு குறைந்து மூங்கில் பற்றாக்குறை ஏற்பட்டுள்ளது. தேசிய வோண்மைக்குழுவின் அறிக்கையில் மூங்கில் தேவையானது நடப்பு 4.274 மில்லியன் கன மீட்டரிலிருந்து 2010-வது ஆண்டில் 7.005 மில்லியன் கன மீட்டராக அதிகரிக்கக்கூடும் என்று தெரிவிக்கப்பட்டுள்ளது. மேலும் தற்போது இருக்கும் சூழ்நிலையில் மூங்கிலை ஒரு வேளாண்மைப் பயிராக வளர்க்கக் அரசு வலத்துறை ஆராய்ச்சியாளர்களை முயற்சி மேற்கொள்ள வலியுறுத்தியுள்ளது. வோளாண்காடுகள், சமுதாயக் காடுகள் மற்றும் தரிசுநில மேம்பாடு போன்ற திட்டங்களில் மூங்கிலுக்கு முக்கியத்துவம் அளிக்கப்பட்டு வருகிறது. தற்போது மூங்கில் வளர்க்கும் முறையானது, அவரவர் சொந்த அனுபவத்தில் வந்ததேயன்றி, விஞ்ஞான பூர்வமானது அன்று. மூங்கிலை ஒரு வேளாண்மைப் பயிராக வளர்க்கக் கூடிய உத்திகளும் இதுவரையில் புத்தகமாக வெளியிடவில்லை இக்குறையைப் போக்குவதற்காக நமது நாட்டிலும், மேலை நாடுகளிலும் வெளியிடப்பட்டுள்ள மூங்கில் ஆராய்ச்சி முடிவுகளைத் தொகுத்து, விவசாயப் பெருமக்கள் மற்றும் ஆராய்ச்சியாளர்கள் பயன்பெறக் கூடியவாறு "வேளாண்மையில் மூங்கில்" புத்தகத்தில் தெளிவாக எடுத்து உரைத்துள்ள இந்நூலின் ஆசிரியர் முனைவர் சண்முகவேல் பாராட்டுக்கு உரியவர். இந்நூலை அழகுற அச்சிட்டு வெளியிட்ட தரணி ஆப்செட் பிரிண்டர்ஸ், சத்தியமங்கலம், பதிப்பகத்தாருக்கு வாழ்த்துக்கள்.

18/9/98

(பா. இளங்கோ)

முகவுரை

மூங்கில் காகித ஆலைகளின் முக்கிய மூலப்பொருளாக இருப்பதிலும், பொருளாதாரத்தில் முக்கிய பங்கு வகிப்பது மட்டுமன்றி அன்றாட வாழ்வில் பயன்படும் பொருளாகவும் உள்ளது என்பது அனைவரும் அறிந்த ஒன்று. நமது நாட்டில் 10.03 மில்லியன் ஹெக்டேர் பகுதியில் அதாவது மொத்த வனப் பகுதியில் 12.8 சதவீதம் மூங்கில் பரவியுள்ளது. நாளுக்கு நாள் பெருகி வரும் மக்கள் தொகையின் மிக அதிகமான உபயோகத்தினாலும், வனப் பகுதியில் ஏற்படும் அழிவினாலும், காகித ஆலைகளின் மிக முக்கிய மூலப் பொருளானதாலும், தென் மற்றும் தென்கிழக்கு ஆசிய நாடுகளின் வனப்பகுதியில் பெரும் நூற்றாண்டில் துவக்கத்தில் காணப்பட்ட மூங்கில் வளமானது தற்போது மிகப் பெருமளவு குறைந்து மூங்கில் பற்றாக்குறை ஏற்பட்டுள்ளது. வனவியல் ஆராய்ச்சியாளர்கள் மூங்கிலுக்கு முக்கியத்துவம் கொடுத்து அதைப் பற்றிய பல்வேறு வகையான ஆராய்ச்சிகளைத் துவக்கியுள்ளனர். தற்போது மூங்கில் வளர்க்கும் முறையானது அவரவர் சொந்த அனுபவத்தினால் வந்ததேயன்றி விஞ்ஞானப் பூர்வமானது இல்லை. மூங்கிலை ஒரு வேளாண்மைப் பயிராக வளர்க்கும் அளவுக்கு விஞ்ஞான பூர்வமான அணுகுமுறையும், சரியான வகையில் மூங்கிலை வளர்க்கக் கூடிய உத்திகளும் இதுவரையில் புத்தகமாக வெளியிடப்படவில்லை. இக்குறையைப் போக்கும் வகையில், தமது நாட்டிலும், மேலை நாடுகளிலும் வெளியிடப்பட்டுள்ள மூங்கில் ஆராய்ச்சி முடிவுகளுடன் எனது ஆய்வு முடிவுகளையும் தொகுத்து விவசாயப் பெருமக்கள் மற்றும் ஆராய்ச்சியாளர்கள் பயன்பெறக் கூடியவாறு இப்புத்தகத்தில் தெளிவாக விளக்கியுள்ளேன்.

மேலும் இந்த நூலை வெளியிட அனுமதி வழங்கிய தேசிய விஞ்ஞான மற்றும் தொழில்நுட்ப குழுமம்(CSIR) புதுடில்லி, அணிந்துரை வழங்கியுள்ள பல்கலைக்கழகத் துணைவேந்தர் டாக்டர் பி. இளங்கோ, நூலை சிறப்பான முறையில் அச்சிட்ட தரணி கணிப்பொறி அச்சகம் திரு. திருச்செந்தில், மேலும் பாரதியார் பல்கலைக்கழகத் தாவரவியல் துறையைச் சார்ந்த அனைவருக்கும் எனது மனமார்ந்த நன்றிகளைத் தெரிவித்துக் கொள்கிறேன்.

01.08.2001

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மூங்கில் தோட்டம் : அமைப்பும், பராமரிப்பு முறைகளும்

6.1 விதை மூலம்

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முன்னுரை :

வனப்பகுதிகளிலிருந்து கிடைக்கும் மிக முக்கிய பொருள் மூங்கில். மூங்கில் புல் இனத்தைச் சார்ந்தது. இருந்த போதும், மூங்கில் புல் இனத்திலிருந்து பின்வரும் இரண்டு முக்கிய காரணங்களால் மாறுபட்டுக் காணப்படுகிறது. 1. மரத்தன்மை கொண்ட இவை பல ஆண்டுகள் உயிர் வாழ்ந்து, ஆண்டுதோறும் பலன்களைக் கொடுக்கின்றன. (2) தனித் தன்மையுடன் கூடிய பூக்கும் முறையும், விதைகளை தோற்றுவிக்கும் முறையும். பொதுவாக, 75 பேரினங்களைச் சார்ந்த 1250 சிற்றினங்கள் உலகம் முழுவதும் பரவிக் காணப்படுவதாக ஆய்வாளர்கள் மூலம் தெரிய வந்துள்ளது. உலகில் உள்ள மூங்கில் இனங்களில் சுமார் 130 சிற்றினங்கள் நமது நாட்டில் இயற்கையாகவே காணப்படுகின்றன. மேலும் 23 இனங்கள் மேலை நாடுகளிலிருந்து இறக்குமதி செய்யப்பட்டுள்ளன. இவை நமது நாட்டில் 10.03 மில்லியன் ஹெக்டர் பகுதியில் அதாவது மொத்த வனப்பகுதியில் 12:8 சதவீதம் பரவியுள்ளது.

நாளுக்கு நாள் பெருகி வரும் மக்கள் தொகையின் மிக அதிகமான உபயோகத்தினாலும் (over - exploitation) வனப் பகுதியில் ஏற்படும் அழிவினாலும் (deforestation), காகித ஆலைகளின் மிக முக்கிய மூலப் பொருளானதாலும் தென் மற்றும் தென்கிழக்கு ஆசிய நாடுகளின் வனப் பகுதிகளில் இந்நூற்றாண்டின் துவக்கத்தில் காணப்பட்ட மூங்கில் வளமானது இந்நூற்றாண்டின் இறுதியில் மிகப் பெருமளவு குறைந்து, மூங்கில் பற்றாக்குறை ஏற்பட்டுள்ளது. சில நாடுகளில் மூங்கில்

உபயோகத்திற்கும், மூங்கிலை வெட்டுவதற்கும், ஏற்றுமதி செய்வதற்கும் கட்டுப்பாடு விதிக்கப்பட்டுள்ளது.

தேசிய வேளாண்மைக் குழுவின் அறிக்கையில் மூங்கில் தேவையானது நடப்பு 4.274 மில்லியன் குயூபிக் மீட்டரிலிருந்து 2005-ல் ஆண்டில் 7.005 மில்லியன் குயூபிக் மீட்டராக அதிகரிக்க கூடும் என தெரிவிக்கப்பட்டுள்ளது. மேலும், இக்குழுவானது மூங்கில் உற்பத்தியைப் பெருக்குவதற்கான சில வழிமுறைகளையும் பரிந்துரை செய்துள்ளது. தற்போது இருக்கக்கூடிய நாட்டில் மூங்கில் வளத்தை திறமையான முறையில் உபயோகித்துத் கொள்வது, மற்றும் பிற விவசாயப் பயிர்களைப் போன்று மூங்கிலையும் ஒரு பயிராக விவசாய பெருமக்களிடம் வளர்க்குமாறு எடுத்துச் சொல்வது, அதற்குரிய வளர்ப்பு முறைகளையும் பொருளாதார வசதியையும், அரசாங்கம் மூலம் செய்து கொடுப்பது போன்ற பரிந்துரைகள் தேசிய வேளாண்மை குழுமம் அரசிற்கு சிபாரிசு செய்துள்ளது.

தற்போது வனவியல் ஆராய்ச்சியாளர்கள் மூங்கிலுக்கு முக்கியத்துவம் கொடுத்து அதைப் பற்றிய பல்வேறு வகையான ஆராய்ச்சிகளை துவக்கியுள்ளனர். இதன் உயிரியல், கருவியல், செல்லியல், செயலியல், சூழ்நிலையில், மூங்கில் வளர்ப்பு முறைகள் மற்றும் உபயோகம் இவைகளைப் பற்றிய ஆராய்ச்சிகள் நடைபெற்று வருகின்றன. அனைத்துலக வனவியல் ஆராய்ச்சி குழுமத்திலிருந்து (IUFRO), மூங்கிலுக்கு தனியான ஆராய்ச்சி திட்டம் ஒன்று 1976 -ம் ஆண்டு துவக்கப்பட்டபின் மூங்கிலைப் பற்றிய ஆராய்ச்சிகள் மேலும் தீவிரமடைந்தன. அதன்பின் 1980 -ஆம் ஆண்டு அனைத்துலக வளர்ச்சி மற்றும் ஆராய்ச்சி சபை (IDRC) வனவியல் ஆராய்ச்சி குழுமம் இரண்டும் இணைந்து மூங்கிலைப் பற்றிய பணி பட்டரை (Workshop) ஒன்றை சிங்கப்பூரில் நடத்தியது 1981-ம் ஆண்டு கியோட்டா அனைத்துலக வனவியல் ஆராய்ச்சி காங்கிரஸ் 1985-ம் ஆண்டு

ஹான்சூவு அனைத்துலக பணிப்பட்டரை மற்றும் 1988, 1991, 1995 -ல் முறையே கொச்சின்(இந்தியா), சியாங்மாய்(தாய்லாந்து), மற்றும் பாலியில்(இந்தோனேசியா) நடைபெற்ற அனைத்துலக மூங்கில் பணிப் பட்டரையிலும் மூங்கில் ஆராய்ச்சிக்கு மிக முக்கியத்துவம் கொடுக்கப்பட்டு, ஆராய்ச்சி கட்டுரைகள் பல நாடுகளிலிருந்தும் இந்த பணிப் பட்டரை மற்றும் காங்கிரசில் சமர்ப்பிக்கப்பட்டு பின் ஆராய்ச்சி கட்டுரைகள் புத்தகமாக வெளியிடப்பட்டது, மூங்கில் ஆராய்ச்சியாளர் களுக்கு வெகுவாக பயன்தக்கது மட்டுமன்றி, மேலும் மூங்கிலைப் பற்றிய ஆராய்ச்சிகள் பன்னாட்டுகளின் ஒத்துழைப்புடன் நடைபெற வழி வகுத்தது.

மூங்கில் தேவையானது, தற்போது உள்ள மூங்கில் வளத்தைவிட மிக அதிகமாக உள்ளது. வெகு விரைவில் காகித ஆலைகளுக்கு முக்கிய மூலப் பொருளான மூங்கில் கிடைப்பது அரிதான ஒன்றாகிவிடும் என்று எதிர்பார்க்கப்படுகிறது. (அனானிமஸ், 1990) பெருமளவு வனப்பகுதி அழிவினாலும், மூங்கில் பெருக்க முறைகளில் உள்ள தடைகளாலும் தேவையான மூங்கிளைப் பெறுவது மிகவும் அரிதான விஷயம். எனவே மூங்கில் உற்பத்தியை பெருக்குவதற்கு (1) மிக அதிகமான இடங்களில் மூங்கிளை வளர்க்க ஏற்பாடு செய்ய வேண்டும். (2) தன்கு பலன் தரக் கூடிய வீரிய மூங்கிலை பெருமளவு திசு வளர்ப்பு மூலம் பெற்று மூங்கில் வளர்ப்போர்களிடம் மலிவான விலையில் அளித்து ஊக்குவிக்க வேண்டும். வேளாண்காடுகள், சமுதாய காடுகள் மற்றும் தரிசு நில மேம்பாடு போன்ற திட்டங்களில் மூங்கிலுக்கு முக்கியத்துவம் கொடுக்க வேண்டும்.

தற்போது மூங்கில் வளர்க்கும் முறையானது. அவரவர் சொந்த அனுபவத்தினால் வந்ததேயன்றி, விஞ்ஞானப் பூர்வமானது இல்லை. மூங்கிலை ஒரு வேளாண்மைப் பயிராக வளர்க்கும் அளவுக்கு, விஞ்ஞான பூர்வமான அணுகுமுறையும், சரியான வகையில் மூங்கிலை வளர்க்கக்

கூடிய உத்திகளும் இதுவரையில் புத்தகமாக வெளியிடவில்லை. இக்குறையைப் போக்குவதற்காக, நமது நாட்டிலும், மேலை நாடுகளிலும் வெளியிடப் பட்டுள்ள மூங்கில் ஆராய்ச்சி முடிவுகளைத் தொகுத்து, விவசாயப் பெருமக்கள் மற்றும் ஆராய்ச்சியாளர்கள் பயன்பெறக் கூடியவாறு மூங்கில் வளர்ப்பு முறைகளும், முக்கியத்துவமும் இப்புத்தகத்தில் தெளிவாக கூறப்பட்டுள்ளது.

அத்தியாயம் - 2

பரவுமுறை

மூங்கில் வெப்ப மண்டலம், மித வெப்ப மண்டலம், பசுமை மாறா காடுகள், மட்டமான டிரோவ்ஷ நிலையுள்ள இடங்களில் மிக அதிகமாகப் பரவியுள்ளது. மொத்த நிலப்பரப்பில் ஏறக்குறைய 14 மில்லியன் ஹெக்டேர் பகுதியில் மூங்கில் காடுகள் உள்ளது. அவற்றில் சுமார் 80 சதவீதம் ஆசியாவில் உள்ளது. ஐரோப்பிய கண்டத்தைத் தவிர அனைத்துப் பகுதிகளிலும், பரவலாக மூங்கில் காணப்படுகிறது. பொதுவாக உலகில் உள்ள அனைத்து வெப்ப மண்டலம், மித வெப்ப மண்டலப் பகுதிகளில் மூங்கில் பரவியுள்ளது.

இந்தியா மூங்கில் உற்பத்தியில் சைனாவிற்கு அடுத்தபடியாக இரண்டாம் இடம் வகிக்கிறது. இந்தியாவில் ஒரு ஆண்டில் சராசரியாக 32,30,000 டன் மூங்கில் உற்பத்தியாகிறது. (பகதூர் 1989) இந்தியாவிலுள்ள வனப்பகுதியில் மிக அதிகமான எண்ணிக்கையில் மூங்கில் சிற்றினங்கள் உள்ளன. மொத்தமாக 130 சிற்றினங்களைக் கொண்ட 75 பேரினங்கள் 10.03 மில்லியன் ஹெக்டேர் இந்திய வனப்பகுயில் பரவியுள்ளது. இது மொத்த வனப்பகுதியில் 12.8 சதவீதமாகும். வெப்ப மண்டல, மித வெப்ப மண்டலப் பகுதிகளில் சமவெளிப் பகுதியிலும், மேலும், மிக உயரமான மலைகளிலும் (7000 மீட்டர் வரை) மூங்கில் பரவிக் காணப்படுகிறது. காஷ்மீரைத் தவிர அனைத்து மாநிலங்களிலும் மூங்கில் பரவி காணப்படுகிறது. (வர்மா மற்றும் பகதூர். 1980).

இந்தியாவில் தாவரங்கள் பரவியுள்ள அமைப்பைப் பொருத்து ஐந்து பெரும் பகுதிகளாக பிரிக்கப்பட்டுள்ளது. அவையாவன. 1. மேடு பள்ளமான சமமற்ற பகுதி, (2) வெப்ப மண்டலப் பகுதி (3) மித வெப்ப மண்டல பகுதி (4) ஈரமுள்ள மற்றும் (5) உலர் வெப்ப மண்டலப் பகுதி,

மூங்கில் பரவியுள்ள முறைகளும் பகுதிக்குப் பகுதி மாறுபட்டு காணப்படுகிறது. குறிப்பிட்ட மூங்கில்கள் பெருமளவு ஒரு பகுதியில் பரவியுள்ளது. இந்தியாவில் காணப்படும் முதன்மை மூங்கில் பேரினங்களில் சில (1) அருண்டுனேரியா (2) பாம்பூஸா (3) சிம்னோ பேம்பூஷா (4) டென்ரோகேலமஸ் (5) டைனோகுளோ (6) ஜெய்ஜான்டிக்ளோவா (7) இன்டோகேலமஸ் (8) அக்லேண்ட்ரா (9) ஆக்ஸிடினேந்திரா (10) பில்லோஸ்டோக்கியா (11) பிளியோபிலாஸ்டஸ் (12) ஜுடோ ஆக்ஸிடேனேந்திரா, (13) சைசோஸ்டேசியம் (14) செமி அருண்டுனேரியா (15) சைனோ பேம்பூசா, இவற்றில் 50 சதவீதத்திற்கும் மேற்பட்டவை அருணாச்சலபிரதேசம், அஸ்ஸாம், மணிப்பூர், மேகாலயா, மிசோராம், நாகாலாந்து, சிக்கிம், திரிபுரா மற்றும் மேற்கு வங்காளம் மாநிலங்களில் பரவியுள்ளன. இது தவிர அந்தமான், மத்தியபிரதேசம் மற்றும் மேற்கு தொடர்ச்சி மலைகளிலும் மூங்கில்கள் பரவலாகக் காணப்படுகிறது.

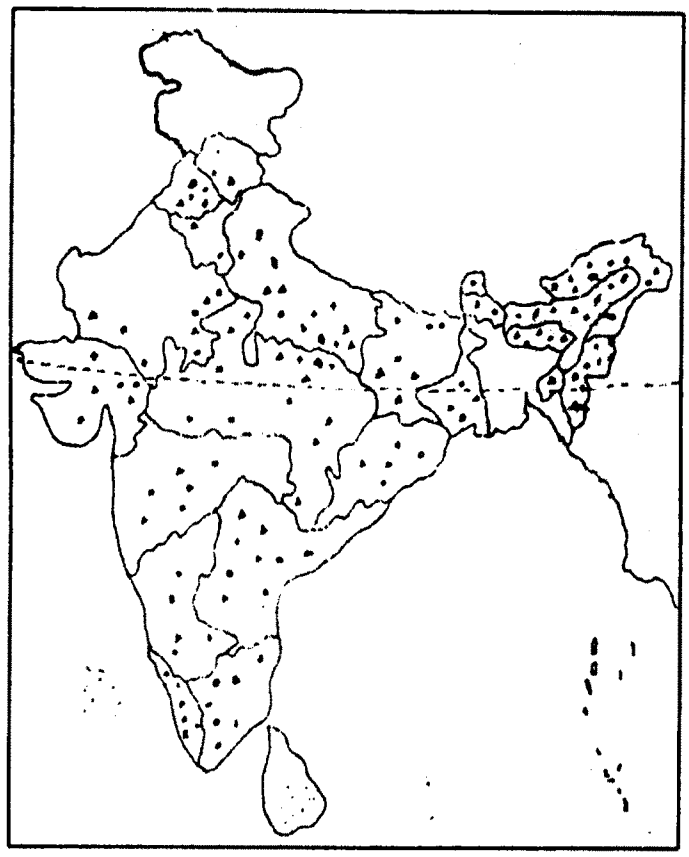
பேம்பூஷா என்ற பேரினமானது மிக அதிகமான அளவில் இந்தியாவில் பரவியுள்ளது. **பேம்பூஷா பேம்போஸ்** (பெரு மூங்கில்) வனப்பகுதியில் இயற்கையாவும், (wild) அல்லது வளர்ப்பு வகையாலும் (cultivation) சமவெளிப்பகுதியிலும், தாழ்வான மலைப் பகுதிகளிலும், மற்றும் தெற்கு தீபகற்பப் பகுதிகளிலும், ஹிமாலாய மலை அடிவாரங்களிலும் பரவியுள்ளது. இதற்கு அடுத்த படியாக **டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்** (சிறுமூங்கில்) தென் மற்றும் மத்திய இந்தியாவின் சமவெளிப் பகுதிகளிலும், வட இந்தியாவில் வறண்ட மலைப்பகுதிகளிலும் பரவி உள்ளது. அந்தமான் நிகோபர் தீவுகளில், பாம்பூஷா, ஆக்சிடேனேந்திரா மற்றும் டைனோகுளோ பெருமளவு பரவியுள்ளது. (**வரைபடம் - 1**) அருண்டேனேரியா, இன்டோகேளமஸ், ஆக்ஸிடேனேந்திரா, சைசோஸ்டக்கியம் மற்றும் மெலோகேனா

பேரினங்கள் மேற்கு தொடர்ச்சி மலைபகுதிகளிலும், வடகிழக்கு இந்தியாவிலும் பரவக் காணப்படுகிறது. சைசோஸஸ் டேக்கியம், பில்லோஸ்டேக்கியா மற்றும் ஜெய்ஜாண்ட்க்ளோவா பேரினங்கள் வடகிழக்கு இந்தியாவில் மிகப் பெருமளவு பரவியுள்ளது.

தமிழ்நாட்டில் பெருமளவு பெரு மூங்கிலும், சிறு மூங்கிலும் உள்ளது, பெரு மூங்கில் ஈரப்பாங்கான இடங்களிலும், சிறு மூங்கில் வறண்ட நிலப்பகுதிகளிலும் காணப்படுகிறது. ***பாம்பூசா டியல்டா, ஆக்சிடினேந்திரா, நைக்ரோசீலியேடா, மற்றும் செபலோஸ்டேக்கியம் பெரிகிரேசில்*** போன்ற பேரினங்களும் ஆங்காங்கே பரவியுள்ளன. மேற்கு தொடர்ச்சி மலைகளில் ஆக்னிடினேந்திரா பேரினத்தைச் சார்ந்த 5 சிற்றினங்களும், ஆக்லேன்ட்ரா பேரினத்தைச் சார்ந்த 8 சிற்றினங்களும் உள்ளன. ***அருன்டுனேசியா சென்சுலேடா*** பேரினம் நீலகிரி மலையில் மட்டும் காணப்படுகிறது. இயற்கையாக காடுகளில் பரவியுள்ள மூங்கிலைத் தவிர, மனிதர்களால் ஏற்படுத்தப்பட்ட மூங்கில் தோப்புகளும் தமிழ்நாட்டில் உள்ளது. மூங்கில் தோப்பு 1992 நிலவரப்படி 1942 ஹெக்டேரில் அமைக்கப்பட்டுள்ளது. தமிழ்நாட்டின் வனப்பகுதியில், 750 மில்லி மீட்டர் முதல் 2600 மில்லி மீட்டர் வரை மழை பெய்யக் கூடிய இடங்களில் 4.5 லட்சத்துக்கும் மேற்பட்ட ஹெக்டேரின் பரவியுள்ளன. (பாலாஜி. 1992).

மூங்கில் உற்பத்தியும், தேவையும் :

இந்தியாவில் 10 மில்லியன் ஹெக்டேர் வனப்பகுதியில் மூங்கில் பரவியுள்ளதாக கண்டறியப்பட்டுள்ளது. **அட்டவணை-1**ல் பல்வேறு மாநிலங்களில் மூங்கில் பரவியுள்ள விவரமும், அதன் மூலம் உற்பத்தியாகும் மூங்கில்களும் கொடுக்கப்பட்டுள்ளது. இதிலிருந்து 4.6 மில்லியன் டன் உற்பத்தியாவது தெரிய வருகிறது. இந்திய வனங்கள் 1987 அறிக்கையின்படி ஒவ்வொரு மாநிலங்களிலும் 1984-85ல் உற்பத்தியான மூங்கிலின் விவரம் **அட்டவணை-2**ல் கொடுக்கப்பட்டுளளது. ஒவ்வொரு மாநிலங்களிலும் உற்பத்தியாகும் மூங்கிலின் எண்ணிக்கையானது ஒவ்வொரு ஆண்டும் வெகுவாக மாறுபட்டுக் காணப்படுகிறது. சில வருடங்களில் மூங்கில் உற்பத்தியானது ஆண்டுதோறும் உற்பத்தியாகும் மூங்கிலை விட மிக அதிகமாகக் காணப்படுகிறது. அருணாசலப்பிரதேசம், அஸ்ஸாம், மேகாலயா, மணிப்பூர், மிசோராம் மற்றும் திரிபுரா போன்ற மாநிலங்களில் மூங்கிலின் குறைவான உபயோகமே இதற்குக் காரணமாக கருதப்படுகிறது. (திவாரி, 1981).



வரைபடம்-1

இந்தியாவில் மூங்கில்களின் பரவுமுறை

* அருண்டுனேரியா	○ ஜய்ஜாண்டிக்ளோ	■ பிலோஸ்டேகிஸ்
▲ பில்லோஸ்டேகிஸ்	I இக்டோகேலமஸ்	▲ குேோஸ்டேகியம்
△ செலபலோ ஸ்டேகியம்	○ மெலோகேனா	⊙ செமி அருண்டுனேரியா
□ சிம்னோ பேம்பூசா	◆ நியூகோசுவா	Ø சைசோஸ்டேகியம்
■ டென்ரோகேலமஸ்	⊹ அக்லன்ட்ரா	⊡ டைனோஸ்டேகியம்
● டைனோகுளோ	+ அக்சிடினேந்திரா	◐ திம்னோகேளமஸ்

அட்டவணை - 1

மாநிலங்களில் மூங்கில் பரவியுள்ள விவரமும், அதன் உற்பத்தியும்

மாநிலத்தின் பெயர்	மூங்கில் பரவுமுறை (மில்லியன் ஹெக்டேரில்)	ஆண்டு உற்பத்தி (மெட்ரிக் டன்னில்)
ஆந்திர பிரதேசம்	1.98	0.255
அருணாசல பிரதேசம்	0.78	0.200
அஸ்ஸாம்	1.00	1.210
பீகார்	0.57	0.200
குஜராத்	0.19	0.046
ஹிமாசல் பிரதேசம்	0.01	0.003
கர்நாடகா	0.60	0.475
கேரளா	0.06	0.108
மத்தியபிரதேசம்	1.49	0.800
மஹாராஷ்டிரா	0.85	0.300
மணிப்பூர்	0.25	0.200
ஒரிசா	1.05	0.489
பஞ்சாப்	....	....
தமிழ்நாடு	0.54	0.009
திரிபுரா	0.28	0.215
உத்திரபிரதேசம்	0.40	0.041
மேற்கு வங்காளம்	0.02	0.008
மொத்தம்	10.03	4.559

அட்டவணை - 2

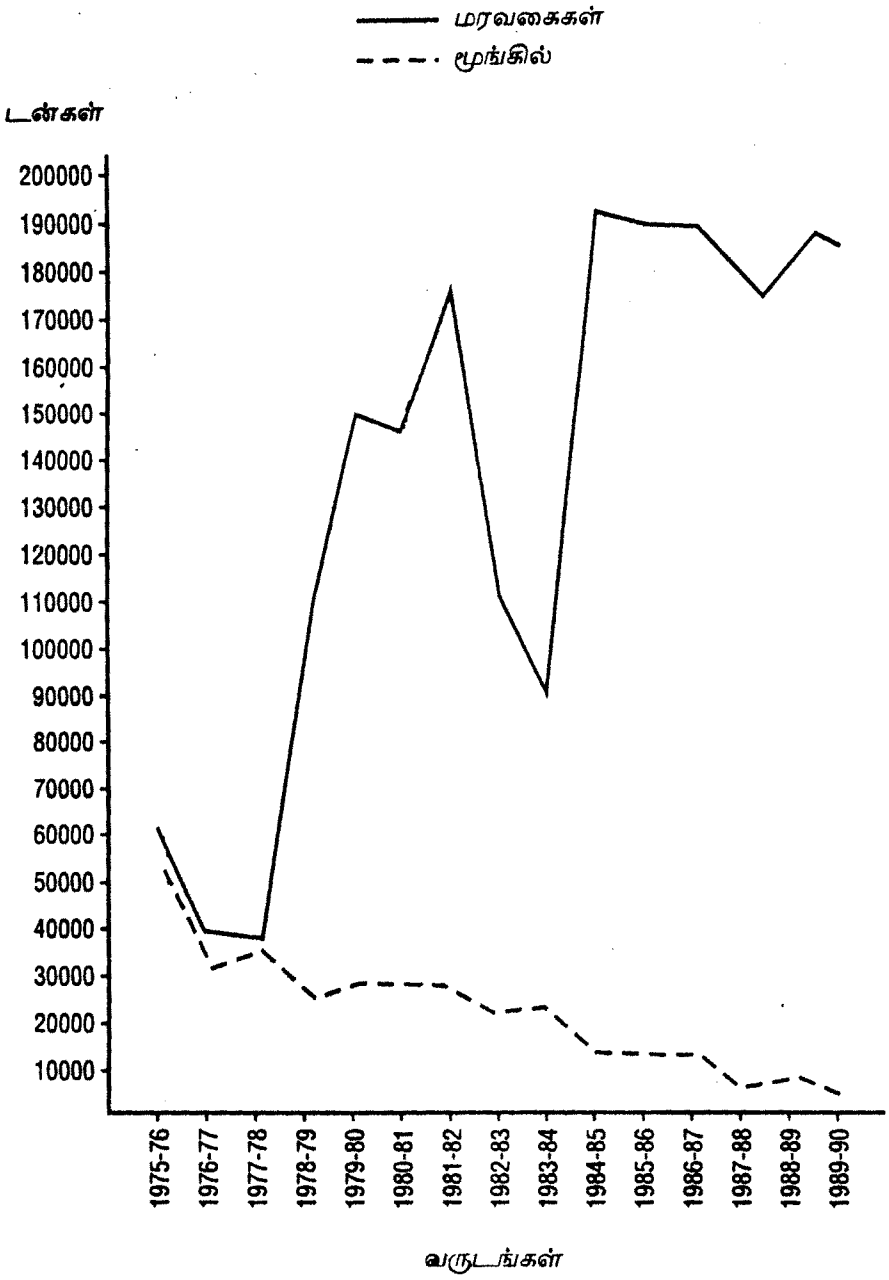
மூங்கில் உற்பத்தி விபரம்

மாநிலம்	மூங்கில் உற்பத்தி (மெட்ரிக் டன்னில்)	மூங்கில் உற்பத்தி எண்ணிக்கையில் (ஆயிரத்தில்)
ஆந்திர பிரதேசம்	0.307	.....
அருணாசல பிரதேசம்	...	147.731
அஸ்ஸாம் (1982 - 1983)	...	1026.000
பீகார்	0.080	.....
கோவா	...	2.865
குஜராத் (1983-84)	0.065	.....
ஹரியானா	...	745.680
ஹிமாசல பிரதேசம்	0.003	.....
கர்நாடகா	0.086	.....
கேரளா	...	1016.343
மத்திய பிரதேசம் (1985-86)	0.316	.....
மஹாராஷ்டிரம் (1983-84)	0.376	.....
மணிப்பூர் (1983-84)	0.001	.....
ஒரிசா	...	162483.262
பஞ்சாப்	0.007	.....
ராஜஸ்தான்	...	5133.071
தமிழ்நாடு (1983-84)	0.011	.....
திரிபுரா	0.028	.....
உத்திரபிரதேசம்	...	9307.000
மேற்கு வங்காளம்	...	104.206
அந்தமான் நிகோபார்	...	1375.610
மொத்தம்	1.276	181341.768

தமிழ்நாட்டில் காகித ஆலை வருவதற்கு முன்னர் மூங்கிலை வீடு கட்டுமானப் பணிகள் மற்றும் விவசாயப் பணிகளுக்கு மட்டுமே பயன்படுத்தி வந்தனர். வியாபார நோக்கில் மூங்கில் பல வகைகளாக வகைப்படுத்தப்பட்டுள்ளன. உதாரணமாக பெரு மூங்கில், தட்டை, மதுரபூட்டு, குருணை, தொக்கு, ரசிபூட்டு மற்றும் தப்பை என ஈரோடு மாவட்டத்தில் வகைப்படுத்தப்பட்டுள்ளது. முதலில் சொல்லப்பட்ட மூன்று வகைகளும் சற்று நீளமாகவும், தடிமனாகவும் உள்ளதால் கட்டுமானப் பணிகளுக்குப் பயன்படுத்தப் பயன்படும். ரசி பூட்டு என்ற வகை தாவரங்களுக்கு ஊன்றுகோலாகவும், தடுப்புச் சுவர் அமைப்பதற்கும் பயன்படுத்தப்பட்டு வந்தது. பின், காகித ஆலைகள் துவங்கிய பின்னர், மூங்கிலே முக்கிய மூலப்பொருளானது, 70-ம் ஆண்டு வாக்கில் 50,000 டன் மூங்கில் காகித ஆலைகளுக்கு பயன்படுத்தப்பட்டது. **வரைபடம்-2**ல் 70-ம் ஆண்டுகளில் 50,000 டன் என்று இருந்த மூங்கில் உபயோகமானது நடப்பு ஆண்டில் 10,000 டன்னாக குறைந்துள்ளது காட்டப்பட்டுள்ளது. மூங்கில் உற்பத்தி குறையவும், அதற்கு மாற்றாக யூகலிப்டஸ் உபயோகம் காகித ஆலைகளில் சிறிது சிறிதாக அதிகரித்ததும் வரைபடத்தில் காட்டப்பட்டுள்ளது.

வனப்பகுதியில் மூங்கில் உற்பத்தி குறைந்து வருவதற்கு பல்வேறு வகையான காரணங்கள் உள்ளது. மிக அதிகமான உபயோகமும் (over-exploitation) பூத்த பின்னர் புதிய கழிகள் தோற்றுவிக்க இயலாமல் உள்ளதும், வறட்சி, காட்டுத்தீ போன்றவையே முக்கிய காரணமாக உள்ளது. மூங்கில் உற்பத்தி குறைவால் காகித ஆலைகளுக்குப் பெருமளவு பாதிப்பு ஏற்படவில்லை. இந்த ஆலைகள் மூங்கிலுக்குப் பதிலாக யூகலிப்டஸ், இதர சுடின மர வகைகள் மற்றும் சர்க்கரை ஆலைகளிலிருந்து வெளிவரும் கழிவுப் பொருட்களை (bagassy) மூலப் பொருளாக பயன்படுத்தத் துவங்கி விட்டன. உதாரணமாக 90,000

மெட்ரிக் டன் காகிதத்தை உற்பத்தி செய்யும் தமிழ்நாடு காகித ஆலை 80,000 டன் யூகலிப்டஸ் மற்றும் சர்க்கரை ஆலை கழிவையும் (bagassy) முக்கிய மூலப்பொருளாகக் கொண்டுள்ளது. ஷேசசாயி காகித ஆலைக்கு ஆண்டுக்கு 35,000 மெட்ரிக் டன் மூங்கில் தேவை உள்ளது. ஆனால் ஆலைக்கு 10-15,000 டன் மட்டுமே மூங்கில் கிடைக்கிறது. மேலும் கட்டுமானப் பணிகள், விவசாயப் பணிகளுக்குத் தேவைப்படும் மூங்கிலைக் கணக்கில் கொண்டு பார்க்கும் போது மூங்கில் தேவையானது 2005-வது ஆண்டில் 1,00,000 டன் எட்டக் கூடும் என எதிர்பார்க்கப்படுகிறது. (பாலாஜி, 1992). இந்த இலக்கை எட்டுவதற்கு வனத்துறை தனது பல்வேறு திட்டங்களின் மூலம் மூங்கில் உற்பத்தியைப் பெருக்குவதற்கு நடவடிக்கை எடுப்பது மிகவும் அவசியமாகிறது.



வரைபடம்-2

காகித ஆலைகளில் மூங்கில் உபயோகம் குறைவதையும்,
இதர மர வகைகள் அதிகரிப்பதையும்
விளக்கும் வரைபடம்

அத்தியாயம் - 3

வகைப்பாட்டியல்

மூங்கில் காகித ஆலைகளின் முக்கிய மூலப்பொருளாக இருப்பதால், பொருளாதாரத்தில் முக்கிய பங்கு வகிப்பது மட்டுமன்றி அன்றாட வாழ்வில் பயன்படும் பொருளாகவும் உள்ளது என்பது அனைவரும் அறிந்த ஒன்று. தற்போது விஞ்ஞானிகளையும், பாமர மக்களையும் கவர்ந்துள்ளது. பாமர மக்களுக்கு மூங்கில் அனைத்தும் ஒரே மாதிரியாகக் காணப்பட்டாலும் 75 பேரினங்களில் சுமார் 1250 சிற்றினங்கள் விவரிக்கப்பட்டு உள்ளது. பல்வேறு கருத்துக்களை மையமாகக் கொண்டு, மூங்கிலை வகைப்பாட்டியல் வல்லுநர்கள் பலவாறாக வகைப்படுத்தியுள்ளனர்.

மூங்கில்களையும், பாம்புசாய்ட் புல் வகையையும் - பாம்புசாய்டியே என்ற துணைக் குடும்பத்தில் கிராமினியே (அல்லது) போயேசியே என்ற குடும்பத்தில் வகைப்படுத்தியுள்ளனர். பெரும்பாலான தாவரவிய லறிஞர்கள் இந்த துணைக் குடும்பத்தையும், குழுவையும் ஏற்றுக் கொண்டுள்ளனர். மூங்கிலுக்கு தனியாக ஒரு குடும்பம் ஏற்படுத்த வேண்டும் என்ற வாக்குவாதமும் உண்டு. (நகாய் 1925). மூங்கிலும், பாம்புசாய் புல் வகையும் பொதுவாக ஒரே முன்னோடிகளில் இருந்து தோன்றியுள்ளது என்ற கருத்தை வெளியிட்டுள்ளனர். பாம்புசாய்ட் புல்வகையில் சரியான முறையில் பேரினங்களை வகைப்படுத்தி உள்ளனர். ஆனால், மூங்கிலைப் பொறுத்த அளவில் பேரினங்களை வகைப் படுத்துவது இன்னும் முற்றுப் பெறாமல் உள்ளது. (சோடர்ஸ்டாம், 1981). பெந்தம் (1883) வகைப்பாட்டை 1913-ல் கேமஸ் என்பவர் மாற்றி அமைத்தார். பின் 1935-ல் கேமஸ் பாம்புசியே என்ற குழுவை மேலும் ஏழு குழுக்களைக் கொண்டு விரிவுபடுத்தினார். அவையாவன.

(1) அருண்டுனேரியே, (2) ஆர்த்தோஸ்டைலிடே (3) சுஸ்கூவே (4) பாம்பு கியேவீரே (5) ஹிக்ளியே (6) சைனான்ட்ரே மற்றும் (7) பக்கிபரே. மேலும் பக்கிபரே என்ற குழுவை நான்கு துணைக் குழுக்களாகப் பிரித்தார். (1) டென்டேராகேலமினே (2) மெலோகேனினே (3) ஹீடோஹூக்சினே (4) பெரிரிர் பாம்புசினே என்பன. ஹால்டம் (1946), பெந்தம் (1883) மற்றும் கேமஸ் (1913) இருவரது வகைப்பாடும் இயற்கையான வகையில் வகைப்படுத்தவில்லை என்ற கருத்தை வெளியிட்டார். 1956-ம் ஆண்டில் ஹால்டம் சூலக அமைப்பைப் பொறுத்து நான்கு வகைப்படுத்தினார். (1) சைசோஸ்டேகியம் (2) ஆக்னிடினேந்திரா (3) பாம்புஷா டென்ரோகேளமஸ் மற்றும் (4) அருண்டினேரியா என்பன.

குரோசர் மற்றும் லீஸ் (1973)-ல் வாஸ்குலார் தொகுப்பின் புற அமைப்பைப் பொருத்து வகைப்படுத்தினார். கிளைடன் மற்றும் ரென்வாய்ஸ் (1786)-ல் பாம்புசாய்டியே என்ற துணைக் குடும்பத்தை 13 குழுக்களாகப் பிரித்தார். பாம்புசாய்ட் புல் வகையை 12 குழுக்களாக பிரித்தார். இவற்றில் துணைக்குழு எதுவும் ஏற்படுத்தப்படவில்லை. மரத்தன்மை கொண்ட அனைத்து மூங்கில்களையும் பாம்புசியே என்ற குழுவில் வைத்ததுடன் இதில் மேலும் 3 துணைக் குழுக்கள் ஏற்படுத்தினார். அவையாவன : (1) அருண்டினியே (2) பாம்புசினே (3) மெலோகேனினே. மேலே சொன்ன வகைப்பாட்டியலைக் கருத்தில் கொண்டு பார்க்கும்போது, மேலும் பல்வேறு காரணங்களை எடுத்துக் கொண்டு மூங்கிலை வகைப்படுத்துவது என்பது இன்றியமையாததாகிறது. இந்த காரணிகளில் இனப்பெருக்க உறுப்புகளின் அமைப்பை கருத்தில் கொண்டு வகைப்படுத்துவது சரியான ஒன்றாகக் கருதினார்கள். பின் வந்த வகைப்பாட்டியல் வல்லுநர்கள்.

முன்ரோ (1869)-ல் மகரந்த அமைப்பைக் கொண்டு மூங்கிலை மூன்று வகையாகப் பிரித்தார். (1) மூன்று மகரந்தப்பைகளைக் கொண்டவற்றை ட்ரைகுலோசே (அல்லது) அருண்டினேரியே (2) ஆறு மகரந்தப்பை கொண்டவை (3) கேரியாப்சிஸ் என்ற கனி வகையைக் கொண்டவை. பிராண்டிஸ் (1899) மூங்கிலின் மலரும் தன்மையைக் கொண்டு மூன்று வகையாகப் பிரித்தார். (1) ஆண்டுதோறும் மலர்வது (2) ஒவ்வொரு பருவத்திலும் மலர்வது (3) சரியான கால அளவி இல்லாத மலரும் தன்மை, பின்னர் வந்த பிளாட்டர் (1929) என்பவர் இந்த கருத்தை ஏற்றுக் கொண்டார். மெக்ளூர் (1966)-ன் மூங்கிலை அதன் ரைசோமின் வளர்நிலையைக் கருத்தில் கொண்டு இரண்டு வகையாகப் பிரித்தார். (1) சிம்போடியல் அல்லது (பன்முக வளர்ச்சி) (பாக்கிமார்ப்) ரைசோம் சிறிய, பருத்த ரைசோம்கள், இதன் பக்கவாட்டில் தோற்றுவிக்கப்படும் மொட்டுகளானது மூங்கில் கழியாக வளர்ச்சி பெறுகிறது. ஒவ்வொரு மூங்கில் கழியும் தனக்கென தனித்தனியே ரைசோம் கொண்டிருக்கும். (2) மோனோபோடியல் (அல்லது) (ஒருமுக வளர்ச்சி) (லெப்டோமார்பிக்) ; இந்த வகையான ரைசோம்களின் உள்பகுதியில் வெற்றிடமும், சற்று நீளமாகவும் காணப்படும். இவைகளில் இருந்து மூங்கில் கழிகள் தோற்றுவிக்கப்படும்.

நட்கவுடா (1990, 1993) மற்றும் ஜானி (1995) போன்றவர்கள் இனப்பெருக்க உயிரியலைக் கொண்டு இரண்டு பெரும் பிரிவுகளாக மூங்கிலைப் பிரித்துள்ளனர். (1) மகரந்தமும், சூலகமும் ஒரே சமயத்தில் முதிர்ச்சி அடையும் நிலையில் உள்ள சிற்றினங்கள் (சிறு மூங்கில்கள்) (2) சூலகம் முதலும் பின் மகரந்தமும் முதிர்ச்சியடையும் நிலையிலுள்ள சிற்றினங்கள். (பெருமூங்கில்கள்) ஜான் (1994)-ல் பாம்புசியே என்ற குழுவை இரண்டு வகையாகப் பிரித்தார். (1) பாம்புசா வகை (2) டென்ரோகோலமஸ் வகை. ஏற்கனவே வெளி ஆகியுள்ள சஞ்சிகைகளைப்

பார்க்கும் போது பாம்புசா, பில்லோஸ்டேகியா, மற்றும் சூடோசூகா மூன்றும் பாம்புசா வகையையும், டென்ரோகேலமஸ் வகையையும் சார்ந்து காணப்படுகிறது. ஆகவே ஜான் என்பவர் (1994) மூங்கிலை அதன் இனப்பெருக்க உயிரியலைக் கொண்டு வகைப்படுத்தியுள்ளார். இந்த வகைப்பாடு மூங்கிலில் இனப்பெருக்கம் உயிரியலை ஆழ்ந்து படித்து, வகைப்பாடு செய்யப் பயன்படுவதுடன், மேலும் பல இனவிருத்தி ஆராய்ச்சிகளுக்கும் பயன்படுவதாக அமைந்துள்ளது.

அத்தியாயம் - 4

வளரிடம்

மூங்கில் பொதுவாக அனைத்து மாநிலங்களிலும் பரவிக் காணப்படுகிறது. மூங்கில் வளரிடமாவது அப்பகுதியிலுள்ள மழையளவு, வெப்பநிலை, கடல் மட்ட உயரம் இவற்றைப் பொருத்து அமைகிறது. பருவமழை அதிகமாக உள்ள இடங்களில் பெருமளவு மூங்கில் வளர்கிறது. சீதோஷ்ண நிலையைப் பொருத்தவரை 1270 மில்லி மீட்டர் முதல் 6350 மில்லி மீட்டர் அளவு மழையுள்ள இடங்களில் மூங்கில் அதிகமாகக் காணப்படுகிறது. 750 மில்லி மீட்டர்-க்கும் குறைவான அளவுள்ள வறண்ட இலை உதிர் காடுகளிலும் மூங்கில் காணப்படுகிறது. மழை அளவு மூங்கில் அதிக அளவு பரவிக் காணப்படுவதற்கும், அதன் வளர்ச்சிக்கும் பங்கு வகிக்கிறது. மூங்கில் காடுகளில் மிக அதிக வெப்பமாக 46.7 டிகிரி செல்சியஸ் மிகக் குறைந்த வெப்பமாக 3.3 டிகிரி செல்சியஸ்-ம் பதிவு செய்யப்பட்டுள்ளது.

கடற்கரையோரங்களில் மூங்கில் அங்கு காணப்படும் குளிர் தன்மையை அடிப்படையாகக் கொண்டே காணப்படுகிறது. கடற்கரை காற்றினால் பாதிக்கப்படாத உள்புற வறண்ட பகுதிகளில் **கல் மூங்கில்** பொதுவாகக் காணப்படுகிறது. கடற்கரை அருகிலும், காற்றில் ஈரப்பதம் உள்ள இடங்களிலும் பெருமூங்கில் அதிகமாகக் காணப்படுகிறது.

மூங்கில் வளர சூரிய ஒளியும் தேவைப்படுகிறது. ஒளி நிழற்பாங்கான இடங்களில் தோற்றுவிக்கப்படும் மூங்கில் கழியானது ஒல்லியாகவும், வளர்ச்சி குன்றிய நிலையிலும் உள்ளது. இருந்த போதிலும் மூங்கில் நாற்றாக உள்ளபோது ஓரளவு நிழற்பாங்கான இடம் இன்றியமையாததாக உள்ளது. மூங்கிலின் அடர்த்தி (அதிக எண்ணிக்கை)க்கும், சூரிய ஒளி இவற்றிற்கிடையில் நேரடித் தொடர்பு காணப்படுகிறது.

மரத்தன்மையுடன் கூடிய மூங்கில் பல்வேறு வகையான மண்வகையிலும் வளர்கிறது. இருந்த போதிலும் ஒவ்வொரு சிற்றினமும் ஒவ்வொரு குறிப்பிட்ட மண் வகையையும், அதற்கேற்ற சீதோஷ்ண நிலையையும் கொண்டுள்ளது. பொதுவாக மூங்கில் மலைகளின் சரிவுகளிலும், சதுப்பு நிலப் பகுதிகளிலும், வயல் ஓரங்களிலும், ஈரமுற்ற, வறண்ட தரிசு நிலப் பகுதிகளிலும் போதிய அளவு ஈரப்பதம், மண்ணிலுள்ள தனிமங்கள் இவைகளைப் பொருத்து வளர்கிறது. **பாம்பூசா பாம்போஸ்** என்று சொல்லப்படும் பெருமூங்கில் மற்றும் ஆக்லெண்ட்ரா களிமண் நிலங்களிலும், ஆறு மற்றும் ஏரிகளின் கரையோரங்களிலும் அதிகமாகக் காணப்படுகிறது. **டென்டோகேலமஸ் ஸ்ட்ரிக்டஸ்** என்று கூறப்படும் கல் மூங்கில் பல்வேறு வகையான சீதோஷ்ண நிலையிலும் பரவலாகக் காணப்படுகிறது. கல் மூங்கிலுக்கு அடுத்தபடியாக பெருமூங்கில் அதிகமாகக் காணப்படுகிறது.

மண்ணில் உள்ள ஈரப்பதமே மூங்கில் வளர்வதற்கு முதன்மையான பங்கு வகிக்கிறது. மண்ணின் புவியியல் அமைப்பு இதற்கு அடுத்த பங்கு பெறுகிறது. ஒரே பாறை வகையிலிருந்து பெறப்பட்ட மண்ணில் மேல் மற்றும் மத்தியில் உள்ள சரிவுகளில், சற்று வறட்சியுடன் கூடிய கரடுமுரடான மண்ணில் சிறு மூங்கில் அதிகமாக வளர்கிறது. ஆனால் அதே பாறையின் அடியிலிருந்து பெறப்பட்ட மண்ணில், ஈரப்பதத்துடன் கூடிய நல்ல மண்வகையில் பெருமூங்கில் அதிகமாகக் காணப்படுகிறது.

கிரானைட், பேசல்ஸ் மற்றும் ரிச்சர்ட்ஸ் போன்ற பாறை வகைகளிலிருந்து பெறப்பட்ட பல்வேறு வகையான மண் வகைகளில் சிறு மூங்கில் வளர்கிறது. மணலுடன் கூடிய மண்ணின் அமைப்பும், மண்ணின் ஈரப்பதமும் இம் மூங்கில் செழித்து வளர மிக முக்கியமான காரணமாக அமைகிறது. இது தவிர சிறு மூங்கில் வறண்ட மண்ணிலும், இலையுதிர் காடுகளிலும் நன்றாக வளர்கிறது.

மூங்கில் மிக அதிகமான அமிலம், காரம், உப்புத்தன்மை கொண்ட மண் வகைகளில் வளருவது இல்லை, அமிலத்திற்கும், காரத்திற்கும் இடையில் காணப்படும் மத்திய நிலையில் (neutral) நன்கு வளர்கிறது. மிக அதிகமான களிமண் நிலங்களிலும், சுண்ணாம்பு தன்மை கொண்ட மண் வகையில், மற்றும் தண்ணீர் தேங்கியுள்ள இடங்களிலும் மூங்கில் வளர்ச்சி காணப்படுவதில்லை. (யாதவ் 1968).

மூங்கில் பரவியுள்ள முறைகளும், மண்ணின் தன்மைகளும் அட்டவணை-3ல் விவரமாகக் கூறப்பட்டுள்ளது.

அட்டவணை - 3

மூங்கில் பரவியுள்ள முறைகளும், மண்ணின் தன்மைகள், ஈரப்பதம் போன்ற விவரங்கள்

வ. எண்	மூங்கிலின் பெயர்	மண்ணின் தன்மைகள்	ஈரப்பதம்	பரவு முறை
1.	2.	3.	4.	5.
1.	அருண்டுனேரியா பால்கேடா	மணல் மற்றும் சுற்களுடன் கூடிய களிமண் பாங்கான இடங்கள்	அதிக ஈரப்பதம்	மேற்கு ஹிமாலய பகுதி (கடல் மட்டத்திலிருந்து 1300 - 2000 மீ வரை)
2.	அருண்டுனேரியா ரெசிமோசா	மணல் மற்றும் கற்களுடன் கூடிய களிமண் பாங்கான இடங்கள்	அதிக ஈரப்பதம்	கிழக்கு ஹிமாலய பகுதி (2200-3050 மீட்டர் வரை)
3.	அருண்டுனேரியா வய்டியானா	களிமண்	அதிக ஈரப்பதம்	பசுமை மாறா சோழாவிலும், தென் பாலைவனப் பகுதி வரை
4.	பாம்பூசா பாம்போஸ்	மணலுடன் கூடிய செம்மண், களிமண், நீர் தேங்கியுள்ள பகுதி	மிக அதிகமான ஈரப்பதம்	இந்தியாவின் அனைத்து இடங்களிலும் பாலைவனப் பகுதி தவிர.
5.	பாம்பூசா பாலிமார்பா	மணல்,களிமண், செம்மண், போன்றவைகள்	மிக அதிகமான ஈரப்பதம்	மேற்கு வங்காளம், அஸ்ஸாம், கேரளா, தமிழ்நாடு
6.	பாம்பூசா டியூல்டா	செம்மண் பகுதி	மிக அதிகமான ஈரப்பதம்	அஸ்ஸாம், மத்திய இந்தியா, மேற்கு வங்காளம்

1.	2.	3.	4.	5.
7.	செபலோஸ்-டேகியம் பேர்கிரசைள் டென்ரோகேலமஸ் ஹேமில்டோனியே	செம்மண், கரிசல் மண், கற்களுடன் கூடிய களிமண் அதிக மணலுடன் மண் வகைகள்	மிக அதிகமான ஈரப்பதம்	அஸ்ஸாம், மத்திய இந்தியா, கேரளா, கர்நாடகா, தமிழ்நாடு, மேற்கு மற்றும் மத்திய ஹிமாலய பகுதிகள்
8.	டென்ரோகேலமஸ் லாஞ்சிஸ்பேதஸ் டென்ரோகேலமஸ் ஸ்டிரிக்டஸ் மெலோகேனா பாம்புசாய்ட்ஸ்	மலைச்சரிவுகளில் பெருமளவு காணப்படுகிறது. மாற்றுப் பயிராகவும் பயிடப்படுகிறது.	மிக அதிகமான ஈரப்பதம்	மேற்கு வங்காளம், அஸ்ஸாம், பசுமை மாறாக் காடுகள் மேற்குத் தொடர்ச்சி மலைகள்.
9.	அக்லடன்ரா டிரவன்கோரிகா ஆக்ஸிடினேந்திரா நைக்ரோசிலியேடா	மணற்பாங்கான பகுதிகள், களிமண், தரிசு நிலம், செம்மண்	மிக அதிகமான ஈரப்பதம்	ஓரிசா, அஸ்ஸாம், மத்திய இந்தியா, அந்தமான் நிகோபர்

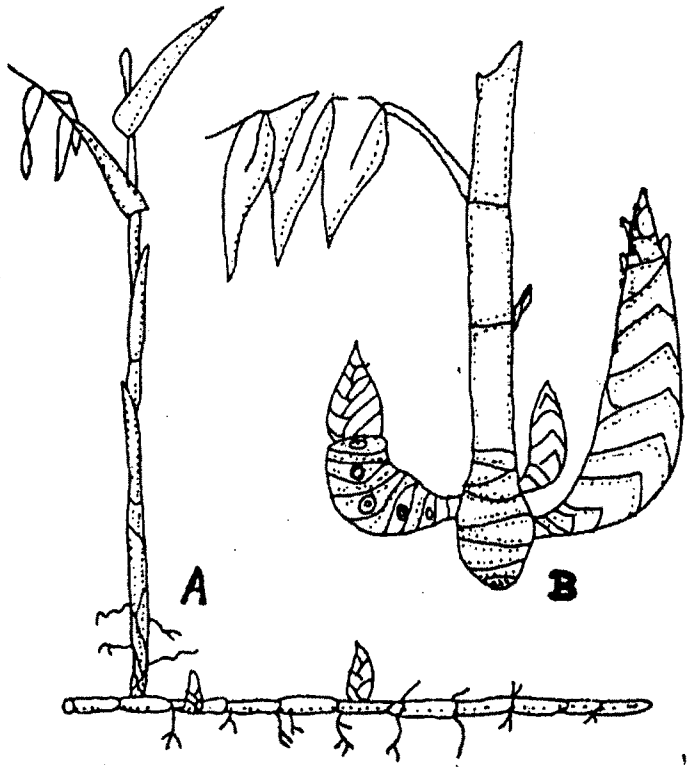
அத்தியாயம் - 5

வளர்ச்சி தன்மைகள்

மூங்கில் வளர்ச்சி தன்மையில் பிற தாவரங்களிலிருந்து மாறுபட்டுக் காணப்படுகிறது.

5.1 மொட்டு வளர்ச்சி :

மூங்கில் சிறப்புத் தன்மையுடன் கூடிய மிகப் பெரிய புல் வகையைச் சார்ந்தது. அதன் ரைசோமின் வளர்ச்சியைக் கொண்டு இருவகையாகப் பிரிக்கப்பட்டுள்ளது. (1) ஒரு மூங்கில் மட்டும் கொண்ட மோனே போடியல் வகை (2) பல மூங்கில் கூட்டாகக் கொண்ட சிம்போடியல் வகை (வரைபடம்-3). ஒரு மூங்கில் தாவரமானது மூன்று வகையான உருவ அமைப்பைக் கொண்டுள்ளது. இந்த மூன்று அமைப்புகளில் ஒருங்கிணைந்த வளர்ச்சியைப் பொருத்தே, மூங்கிலின் முழுமையான வளர்ச்சி அமைகிறது. மூங்கில் கழி, ரைசோம் மற்றும் வேர் என்பன மூன்று அமைப்புகள். மூங்கில் கழி கல்ம்ஸ் (culm) என அழைக்கப் படுகிறது. சிறிய மூங்கில் (young bamboo) தாவரமானது ஒரு புல்லின் (grass) அமைப்பை ஒத்துக் காணப்படுகிறது. இவற்றில் முதலில் ரைசோம் முழுமையான வளர்ச்சியை முதலாமாண்டில் பெறுகிறது. இந்த ரைசோமிலிருந்து முளை மொட்டுகள் (அல்லது) போத்துக்கள் தோற்று விக்கப்படுகின்றன.



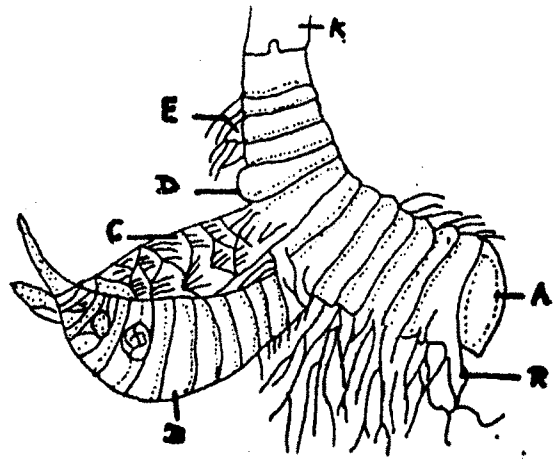
வரைபடம்-3

A - மோனோபோடியல் வகை

B - சிம்போடியல் வகை

ரைசோமில் தோன்றியுள்ள மொட்டுக்களானது, முதலில் தட்டையாகவும் 2.5 செ.மீட்டருக்கும் குறைவான சுற்றளவு (diameter) கொண்ட தாகவும், அதிகமாக செதில்களால் (scales) சூழப்பட்டுமிருக்கும், இந்த செதில்களை ஒவ்வொன்றாக நீக்கி விட்டுப் பார்க்கும்போது, மொட்டில் சிறு மூங்கில் கரு வடிவில் இருக்கும். ஒவ்வொரு மொட்டிலும் 35க்கும் மேற்பட்ட மிகச்சிறிய கணுவிடைப் பகுதி (inter nodes)கள் காணப்படும். இந்த அமைப்பைக் கொண்ட மொட்டுகள் மழைக் காலங்களில் தரைக்கு மேலே வரத் துவங்குகிறது.

ரைசோம் மொட்டானது மூங்கிலாக வளரத் துவங்குமுன்னர் முதலில் உருவாவது ஒரு சிறிய ரைசோம் ஆகும். (வரைபடம்-4, படம்-1) ரைசோம் மொட்டில், ரைசோம் உருவானபின், மொட்டுகளுக்குத் தேவையான, நீர் மற்றும் கனிமங்களை மண்ணிலிருந்து இந்த சிறிய ரைசோம் மூலமாக பெறுகின்றன. (வரைபடம்-5). மூங்கில் வளரும் போது அதனைச் சூழ்ந்துள்ள செதில்களே முக்கிய பங்கு வகிக்கிறது. (படம்-2). ஒவ்வொரு கணுவிடைப் பகுதியும் ஒரு செதில்களால் சூழப்பட்டிருக்கும். ஆனால் அடியிலுள்ள கணுவிடைப்பகுதி மட்டும் ஒன்றுக்கும் மேற்பட்ட செதில்களால் சூழப்பட்டிருக்கும். இந்த செதில்கள் மொட்டுக்களை பூச்சி மற்றும் நோய் தாக்குதலிலிருந்து பாதுகாக்கிறது.



வரைபடம்-4

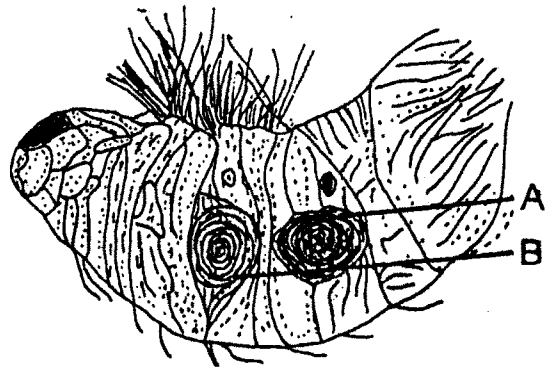
புதிய சிறிய ரைசோம் தோன்றியிருப்பதைக் காட்டுகிறது

A - ஒரு பருவ தாய் ரைசோம்

B,C - தாய் ரைசோமிலிருந்து தோன்றியுள்ள இரு புதிய ரைசோம்

D,E - ரைசோமில் காணப்படும் மொட்டுக்கள்

R - வேர்கள்



வரைபடம்-5

ரைசோமில் தோன்றியுள்ள இரு புதிய மொட்டுக்கள்

A, B தெளிவாகக் காட்டப்பட்டுள்ளது

1. வேர்ப் பகுதிகளில் தட்டையான ரைசோம் தோன்றுவது

2. கணுவிடைப் பகுதியில் செதில்கள் சூழப்பட்டுள்ளதைக் காணலாம்

ஒவ்வொரு மொட்டும், மிகச்சிறிய மூங்கிலையும் (culms) அதனுடன் கூடிய ரைசோமையும் கொண்டு சிறிய மூங்கிலாகக் காட்சி தருகிறது. மூங்கில் வளர்ச்சி உச்சியிலுள்ள செல்களின் மூலம் நடைபெறுவதில்லை. கணுவிடைப் பகுதியின் மூலமாகக்தான் மூங்கிலில் உயர வளர்ச்சி நடைபெறுகிறது. அடியிலுள்ள கணுவிடைப் பகுதியில் முதலில் வளர்ச்சி நடைபெறுகிறது. அடிப் பகுதியிலுள்ள கணுவிடைப் பகுதியில் தோன்றிய நீள் வாட்ட வளர்ச்சி படிப்படியாக, உயரத்திலுள்ள உச்சியில் உள்ள கணுவிடைப் பகுதியை சென்றடைகிறது. ஒவ்வொரு கணுவிடைப் பகுதி விரிவாக்கமும் 15 தினங்களுக்குள் முடிந்து விடுகிறது. முதலில் மூங்கிலின் உயர வளர்ச்சியானது மிக மெதுவாக நடைபெறுகிறது. (படம்-3) பின்னர் 3 மீட்டர் உயரத்தை எட்டிய பின்னர், வெகு விரைவாக உயர வளர்ச்சி அடைகிறது. அதாவது சராசரியாக ஒருநாளைக்கு 30 செ.மீ. வளர்ச்சி அடைகிறது. (சண்முகவேல் 1995). 35 மீட்டருக்கும் மேல் உயரத்தைக் கொண்டுள்ள மூங்கில் கூட 2-லிருந்து 4 மாதங்களுக்குள் வளர்ச்சியை அடைந்து விடுகின்றன. உயர வளர்ச்சியை எட்டிய பின்னர் கணுவிடைப் பகுதியில் உள்ள செதில்கள் விழத் துவங்குகிறது. (படம்-4) கணுவில் காணப்படும் பக்கவாட்டு கிளை மொட்டுக்கள் மிக விரைவாக வளர்ச்சியடைந்து கிளைகளைத் தோற்றுவிக்கின்றன (branches). இந்த கிளை மொட்டு ஒரு மாதத்தில் முழு வளர்ச்சியடைந்து கிளையை ஏற்படுத்துகிறது. பின்னர் கிளைகளிலுள்ள மொட்டுக்கள், பகுப்படைந்து இலைகளைத் தோற்றுவிக்கிறது. இலைகள் தோன்றியவுடன் ஒரு மூங்கிலின் முழு வளர்ச்சி நிறைவு பெற்று விடுகிறது. பின்னர் அதனுடைய கடினத் தன்மையில் மட்டும் சில மாற்றங்கள் ஏற்படுகின்றன. மிக வேகமாக வளர்ச்சி நடைபெறும் இந்த மூங்கிலில் சில சமயம், மொட்டுகளைச் சூழ்ந்துள்ள செதில்களை கிழித்துக் கொண்டு வரும் போது அதன் சத்தம் கூட கேட்க முடிகிறது.

3. மூங்கில் உயர வளர்ச்சி

A - 2-ம் நாள் - 12 செ.மீ

B - 4-ம் நாள் - 20 செ.மீ

C - 6–ம் நாள் – 53 செ.மீ

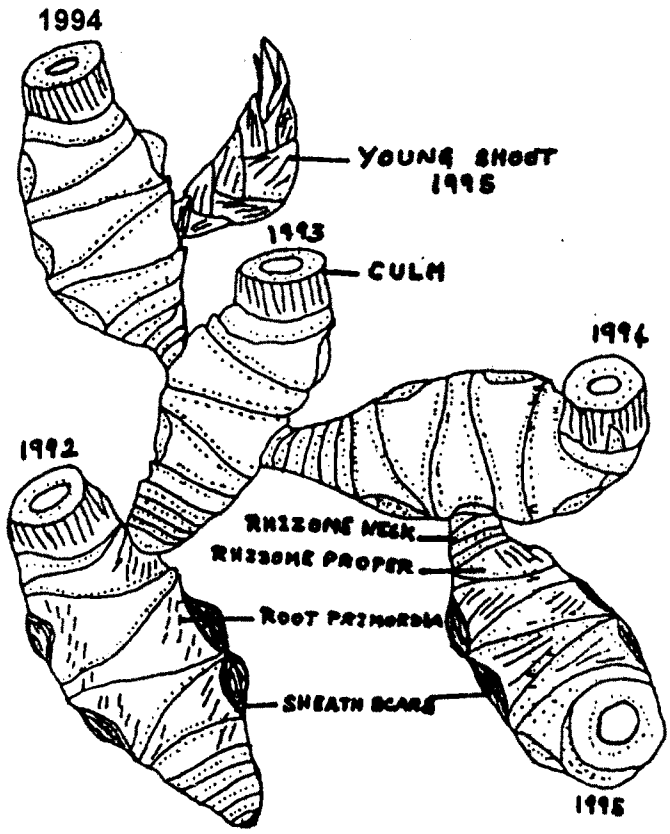
D - 8–ம் நாள் – 76 செ.மீ

4. கணுவிடைப் பகுதியைச் சூழ்ந்துள்ள செதில்கள் கழன்று உள்ளது.

5.2 மூங்கில் (culm) திரள் (clump)

பெருமளவு மூங்கில் வகைகள் **மூங்கில் திரள்** (அல்லது) **மூங்கில் கூட்டத்தை** ஏற்படுத்துகின்றன (clump). (படம்-5) புதிதாக நடப்பட்ட மூங்கில் தாவரமானது ரைசோம்களை ஏற்படுத்துகிறது. இவற்றிலிருந்து மேலும் ரைசோம் தோன்றுகின்றன. இதிலிருந்து புதிய மூங்கிலை தோற்றுவிக்கும் **மூங்கில் மொட்டுக்கள்** தோன்றுகின்றன. புதியதாக தோற்றுவிக்கப்படும் ரைசோம்களின் எண்ணிக்கை வேறுபட்டுக் காணப்படும். (வரைபடம்-6). இந்தியாவில் பொதுவாக மழைக் காலங்களில் மூங்கில் மொட்டுகள் தோன்றுகின்றன. இரண்டு வகையான ரைசோம் மொட்டுகள் தோன்றுகின்றன. (1) செதில்களுடன் கூடிய கூர்மையான மொட்டு (2) தட்டையான மொட்டு, முதலாவது ரைசோமாக மாறுகிறது. இரண்டாமாவது புதிய மூங்கிலைத் தோற்றுவிக்கிறது. கூர்மையான மொட்டுகள் கோடை காலங்களிலும், தட்டையான மொட்டுகள் மழைக் காலங்களிலும் தோன்றுகின்றன. சில இடங்களில் மூங்கில் மொட்டுக்களை உணவாகவும், ஊறுகாய் செய்வதற்கும் பயன்படுத்துகிறார்கள்.

5. தோட்டவகை மூங்கிலில் காணப்படும்
மூங்கில் திரள்கள்



வரைபடம்-6

சிம்போடியல் வகை மூங்கில் ரைசோம் பல்வேறு ஆண்டுகளில்
தோன்றியுள்ள ரைசோம்கள் தெளிவாகக் காட்டப்பட்டுள்ளது.

சில மூங்கில்கள் உள்பகுதி வெற்றிடமாக (hollow) உள்ள கழிகளையும், (**பெருமூங்கில்**), சில வெற்றிடமற்ற (solid) கழிகளையும் கொண்டுள்ளன. (**சிறுமூங்கில், டைனோகுளோ, பாம்பூசா பிக்மி**). சில மூங்கில்களில் பித்களும் (pith) காணப்படுகிறது. (**ஆக்டினோகிளேடம் - வெர்டிசிலேடம்**).

5.3 ரைசோம்கள் : (Rhizomes)

ரைசோம்கள் பொதுவாக உயர வாக்கிலேயே (upward) வளர்ச்சி யடைகின்றன. ரைசோம் வளர்ச்சியின் போது சூரிய ஒளிபட நேர்ந்தால் அதன் வளர்ச்சி நின்று விடுகிறது. ரைசோம் வளர்ச்சியானது அனைவரும் எண்ணுவது போல ஓரங்களில் மட்டும் நடைபெறு வதில்லை. பொதுவாக இதன் வளர்ச்சி அனைத்து பகுதிகளிலும் நடைபெறுகிறது. சரியான முறையில் பராமரிக்கப்படாத மூங்கில் திரளில் (congested) மட்டும் (படம்-6) புதிய மூங்கில் குருத்தானது ஓரங்களில் தோன்றுகிறது. புதிய மூங்கில் குருத்தானது மூங்கில் திரள்களின் நடுவில்கூட தோன்றுகின்றன.

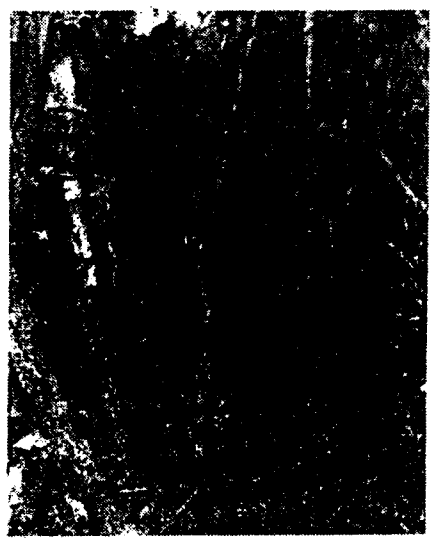
5.4 மலருதல் : (Flowering)

மூங்கில் மற்ற தாவரங்களிலிருந்து அதன் மலரும் தன்மையில் முற்றிலும் மாறுபட்டுக் காணப்படுகிறது. பெரும்பாலான மூங்கில்கள் 3லிருந்து 120 ஆண்டுகளுக்கு ஒருமுறை தான் மலரும் தன்மை கொண்டுள்ளது. (ஜென்சன் 1976). பொதுவாக மூன்று வகையான பூக்கும் தன்மை காணப்படுகிறது. (1) குறிப்பிட்ட கால அளவில் மலரும் தன்மை கொண்டவை (2) கால அளவு இல்லாமல் எப்போதாவது மலரும் தன்மை கொண்டவை (3) ஒவ்வொரு ஆண்டும் மலரும் தன்மை கொண்டவை.

குறிப்பிட்ட கால அளவில் மலரும் (Gregarious) தன்மை கொண்ட மூங்கிலில் ஒரே சமயத்தில் விதைகளிலிருந்து தோன்றிய அனைத்து மூங்கில்களும் சேர்ந்து கூட்டாக மலர்கிறது. மலர்ந்தபின் அனைத்து

மூங்கில்களும் இறந்து விடுகின்றன. அதாவது அதன் காலம் முடிந்து, புதிய மூங்கில் மொட்டுகள் தோன்றுவது நின்று விடுகிறது. கால அளவு இல்லாமல் (irregular (a) sporadic) மலரும் தன்மை கொண்ட மூங்கில்கள், எப்போது வேண்டுமானாலும் மலருகின்றன. (உம்) ***பாம்பூசா பாலிமர்பா, ப.பேம்போஸ், மெலோகேளா பேக்கிபெரா.*** மலர்ந்த பின் அனைத்து மூங்கில்களும் இறந்து விடாமல் மீண்டும் புதிய மொட்டுகளை தோற்றுவிக்கும் நிலைக்குத் திரும்புகின்றன. (உம்.) ***சிறுமூங்கில், டென்ரோகேலமஸ் ஹெமில்டோனி, ஆக்ஸிடினேந்திரா*** வகைகள் போன்றவை. சில மூங்கில்கள் ஆண்டுதோறும் மலர்கின்றன. (***இன்டோகேலமஸ் வெய்டியனஸ், பாம்பூசா அட்ரா*** மற்றும் ***ஆக்லேன்ட்ரா ஸ்கிரிப்டோரியா.***

இவ்வாறு உள்ள தனித்தன்மையுடன் கூடிய பூக்கும் முறையால் மூங்கில்கள் பூப்பூப்பதற்கும், அதன் மூலம் விதைகளை உற்பத்தி செய்வதற்கும் நீண்ட இடைவெளி காணப்படுகிறது. இதனால் மூங்கில் இனங்களுக்கு இடையே உள்ள தொடர்பை பற்றியும், வீரிய ஒட்டுமுறை



6. சரியாக பராமரிக்கப்படாத மூங்கில் திரள்

ஆய்வு செய்வதற்கும் தடையாக உள்ளது. மேலும் மூங்கில் தோட்டங்களை ஏற்படுத்துவதற்கும் கடினமான ஒன்றாக உள்ளது. "தேர்வு செய்தல்" (selection) என்ற ஒரே முறையே மூங்கில் உற்பத்தியைப் பெருக்குவதற்கு ஒரே வழியாக உள்ளது. (ஜான் 1994). தற்போது திசு வளர்ப்பின் மூலமாக மூங்கிலில் பூக்கும் தன்மையை ஏற்படுத்துகின்றனர் (நட்கவுடா 1990). இவ்வாறு செற்கை முறையில் மலரச் செய்யும் முறையானது, அதிகமான விதைகள் உருவாகவும், வீரிய ஒட்டுமுறை ஆராய்ச்சிகளுக்கும் வழிவகுக்கிறது. மூங்கில் சிற்றினங்களில் மலருவதில் காணப்படும் கால இடைவெளி வருமாறு :

ஆக்லெண்ட்ரா ட்ரவன்கோரியா	:	7 ஆண்டுகள்
டிரபனோஸ்டேகியம் பால்கேடம்	:	28 - 30 ஆண்டுகள்
தம்னோகேலமஸ் ஸ்பேதியிலோரஸ்	:	16 - 17 ஆண்டுகள்
ஹிமலாயகேலமஸ் பல்கோனோரி	:	30 ஆண்டுகள்
அருண்டினேரியா ரெசிமேசா	:	30 ஆண்டுகள்
டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்	:	30 - 70 ஆண்டுகள்
டென்ரோகேலமஸ் ஹெமில்டோனி	:	30 - 40 ஆண்டுகள்
பாம்புசா டியூல்டா	:	30 - 60 ஆண்டுகள்
பாம்புசா பாலிமார்பா	:	55 - 60 ஆண்டுகள்
பாம்புசா பேம்போஸ்	:	30 - 45 ஆண்டுகள்
மெலோகேனாபக்கிபெரா	:	45 ஆண்டுகள்
சைசோஸ்டேசியம் சிற்றினங்கள்	:	30 - 40 ஆண்டுகள்

5.5 செயற்கை முறையில் மூங்கிலை மலரச் செய்தல் :

புனேயிலுள்ள தேசிய வேதியியல் ஆய்வகத்தில் டாக்டர். நட்கவுடா என்ற விஞ்ஞானியின் தலைமையில் செயற்கை முறையில் மூங்கிலில் பூக்கும் முறையை ஏற்படுத்துவது பற்றிய ஆராய்ச்சிகள் நீண்ட நாட்களாக நடைபெற்று வந்தது. அந்த ஆராய்ச்சிகளின் வெற்றியாக 1990-ம் வருடம்

அந்த ஆய்வகத்தில் மூங்கிலை மலரச் செய்தனர். இந்த வெற்றியானது மூங்கிலைப் பற்றிய பல்வேறு ஆய்வுகளுக்கும், மரபியல் முன்னேற்றத்திற்கும் அடிகோலியது. இதன் மூலமாக இரண்டு வெவ்வேறு காலங்களில் மலரும் தன்மையுள்ள சிற்றினங்களை ஒரே சமயத்தில் மலரச் செய்தனர். இது "வீரிய ஒட்டுமுறை" ஆராயச்சிகளுக்குப் பெரிதும் உதவியது. மேலும் மூங்கில் மலரும் தன்மையை செல்லியல் மூலமாகவும், உயிர் வேதியியல் மூலமாகவும் அறியவும் உதவியது.

மூங்கில் மலருவதின் இன்னொரு சிறப்பம்சம் என்னவெனில் ஒரே மூங்கிலில் இருந்து பெறப்பட்ட விதைகளிலிருந்து, தோன்றிய மூங்கில்கள் எந்த நாட்டில் எந்த பகுதியில், எப்போது நடப்பட்டிருந்தாலும் அவைகள் அனைத்தும் ஒரே சமயத்தில் மலர்கின்றன. வேறு எந்த தாவர வகைகளிலும் இந்த சிறப்பம்சம் கிடையாது.

அத்தியாயம் - 6

மூங்கில் தோட்டம் அமைப்பும், பராமரிப்பு முறைகளும்

மூங்கில் தோட்டத்தை 1) நேரடியாக விதைகள் மூலமும், (2) வேர் மற்றும் ரைசோமுடன் கூடிய மூங்கில் கழியை நடுவதன் மூலம், (3) கிளைகளற்ற மூங்கில்கழி, ரைசோமுடன் கூடிய வேருடன் நடுவதன் மூலமும், (4) ரைசோமை வேருடன் நடுவதன் மூலமும் (5) துளிர் விடக் கூடிய ஒரு வருட மூங்கில் கழியை நடுவதன் மூலமும் (6) மூங்கிலை பல துண்டுகளாக வெட்டி நடுதல் முறையிலும், (7) கிளைகளை நடுவதன் மூலமும் மற்றும் (8) திசு வளர்ப்பு முறையில் தோன்றிய நாற்றுக்களை நடுவதன் மூலமும் மூங்கில் தோட்டங்களை அமைக்கலாம். இனி ஒவ்வொரு முறைகளையும் விரிவாகக் காணலாம்.

6.1 விதை மூலம் :

6.1.1 விதையின் பண்புகள் :

விதைகளின் மூலம் மூங்கில் தோட்டம் அமைப்பது என்பது மிகவும் கடினமான ஒன்றாகும். ஏனெனில் மூங்கிலின் காலவரையற்ற பூக்கும் தன்மை, மற்றும் விதைகள் மிகக் குறுகிய காலமே உயிர்த்தன்மை கொண்டவை. மெலோகேனா பேக்கிபெரா என்ற சிற்றினத்தை தவிர அனைத்து மூங்கிலின் விதைகளும் நெல் அல்லது கோதுமை போன்ற உருவ ஒற்றுமையும், மிகக் குறைந்த எடை அளவும் கொண்டதாகும். விதைகளை மூங்கில் மலரும் போது காடுகளிலிருந்து சேகரிக்க வேண்டும். விதைகளை சேகரிக்க பிப்ரவரி முதல் ஜூலை வரை உள்ள மாதங்கள் ஏற்றதாகும். ஒரு கிலோ விதை 75,000 முதல் 1,05,000 வரை எண்ணிக்கை கொண்டது. மூங்கில் விதையின் உயிர்தன்மை சிற்றினத்திற்கு சிற்றினம் மாறுபட்டுக் காணப்படுகிறது. பொதுவாக 1 - 2 மாதங்கள் வரை உள்ளது. பாம்பூசா டியூல்டா சிற்றினத்தைச் சார்ந்த விதைகளை, அதிலுள்ள ஈரத்

தன்மையை அகற்றிவிட்டு, சிலிகா ஜெல்லில் வைக்கும்போது அதன் உயிர்த்தன்மை 18 மாதங்கள் வரை நீட்டிக்கப்படுகிறது. சரியான வெப்ப நிலையிலும், ஈர நிலையிலும் வைக்கும் போது சிறு மூங்கிலின் உயிர்த்தன்மை 34 மாதங்கள் வரை உள்ளது. (குப்தா மற்றும் சூட், 1978). சில சிற்றினங்களின் விதைகளின் உயிர்த்தன்மை கால அளவு வருமாறு.

(1)	பாம்பூசாடியூல்டா	:	30 - 35	நாட்கள்
(2)	டென்டேரோகேலமஸ் லாஞ்சிஸ்பேதஸ்	:	55	நாட்கள்
(3)	பாம்பூசா பேம்போஸ்	:	65	நாட்கள்
(4)	தைரேஸ்டேசிஸ் சியாமென்சிஸ்	:	27	மாதங்கள்

6.1.2 விதை ஊன்றுதல் :

நேரடியாக விதைகளை மண்ணில் ஊன்றுவதற்கு (sowing) மண்ணில் 10-15 செ.மீ. குழி தோண்ட வேண்டும். விதைகளை நேர்கோட்டிலோ (அல்லது) 3 மீ இடைவெளியிலோ நட வேண்டும். விதைகளை 48 மணி நேரம் நீரில் ஊறச் செய்தபின் நட வேண்டும். 1.25 கி.கி. விதைகளானது 1 ஹெக்டேர் பரப்பில் ஊன்ற தேவைப்படுகிறது. விதை மூலம் தோட்டம் அமைப்பது எளிதாக இருந்தாலும், பெரும்பாலும் இம்முறை பின்பற்றப் படுவதில்லை. ஏற்கனவே குறிப்பிட்ட காரணங்களைத் தவிர, களைகள் அதிகமாக வளர்வதாலும், விதைகளை ஊன்றிய பின்னர், விதைகளை தின்னும் பறவைகளாலும், எலி போன்றவைகளாலும் பாதிப்பு வருவதாலும், இம்முறையில் தோட்டம் அமைப்பது வெற்றி பெறுவதில்லை.

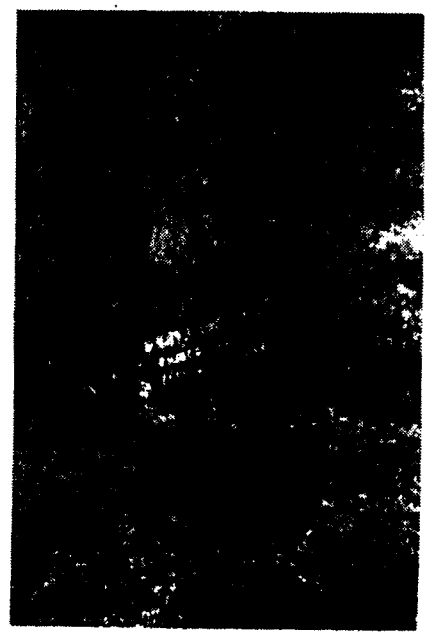
6.1.3 நாற்று நடுதல் :

மண்ணில் நேரடியாக விதைகளை ஊன்றி, மூங்கில் தோட்டம் அமைப்பதில் பல பிரச்சினைகள் உள்ளன. (1) சரியாக விதை முளைப்பின்மை (2) முளைத்த செடியிலும் மிகக் குறைவான வளர்ச்சி

(3) விலங்குகளால் ஏற்படும் பாதிப்பு போன்றவை. ஆகையால் நாற்றாங்கால் அமைத்து அதில் மூங்கில் நாற்றுக்களைப் பெற்று, மற்ற இடங்களில் நடச் செய்யும் முறை பின்பற்றப்படுகிறது. நாற்றாங்கால் மூங்கில் நாற்றுக்களை நடச்செய்யும் இடத்தின் அருகில் அமைத்துக் கொள்வது நன்மை பயக்கும்.

மூங்கில் நாற்றானது ஒரு சிறிய புல்லைப் போலவே (படம்-7) உள்ளது. மூங்கில் நாற்றுக்களை நடும்போது அதிகக் கவனம் எடுத்துக் கொள்வது அவசியமாகிறது. மழைப்பருவ காலம் துவங்குமுன்பே நாற்று நடுவதை முடித்து விடுதல் அவசியம். நடப்பட்ட (படம்-8) நாற்றுகளுக்கு காலையும், மாலையும் நீர்ப் பாய்ச்சுதல் அவசியம். களைகள் தோன்றினால் அவ்வப்போது நீக்கி விடுவது நல்லது. தண்ணீர் தேங்கி நிற்காமல் பார்த்துக் கொள்வதுடன், சிறு பூச்சிகள், விலங்கினங்களிலிருந்து பாதிப்பு ஏதும் வராமல் பாதுகாப்பது இன்றியமையாததாகும்.

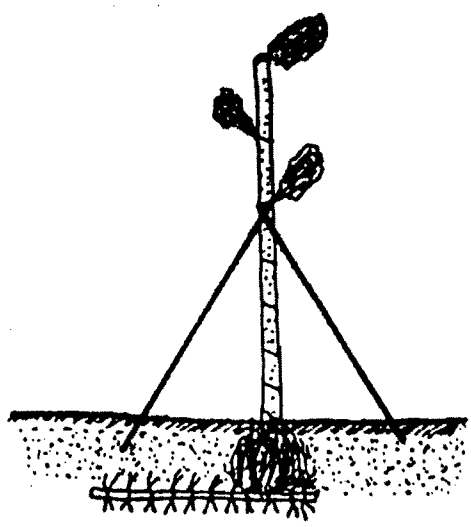
7. புல்லை ஒத்துக் காணப்படும் மூங்கில் நாற்று



8. நடவு செய்யப்பட்ட மூங்கில் நாற்று

6.2 வேர் மற்றும் ரைசோமுடன் கூடிய மூங்கில் கழியை நடுதல் :

இம்முறையில் புதிய மூங்கில் கழியையோ அல்லது முந்தைய பருவத்தில் தோன்றிய கழியையோ பயன்படுத்தலாம். கழியில் உள்ள மேல்பகுதியை நீக்கிவிட்டு, கீழ்ப்பகுதியில் உள்ள கழியை, கிளையுடன் உபயோகிக்க வேண்டும். (வரைபடம்-7). அந்த கழியில் உள்ள ரைசோம் நல்ல நிலையிலும், அதிகமான முளை மொட்டுக்களை கொண்டதாகவும் இருக்கும்படி பார்த்துக் கொள்ள வேண்டும். ரைசோமின் நீளமானது 40-60 செ.மீ. இருக்க வேண்டும். அத்துடன் குறைந்தபட்சம் 10 கணுக்களும், அதில் முளை மொட்டுகளும் இருக்க வேண்டும். ரைசோமை ரம்பம் கொண்டு, மிகக் கவனமாக வெட்ட வேண்டும். வெட்டும்போது அதில் உள்ள முளை மொட்டுகளுக்கு பாதிப்பு வராமல் பார்த்துக் கொள்ள வேண்டும்.



வரைபடம்-7

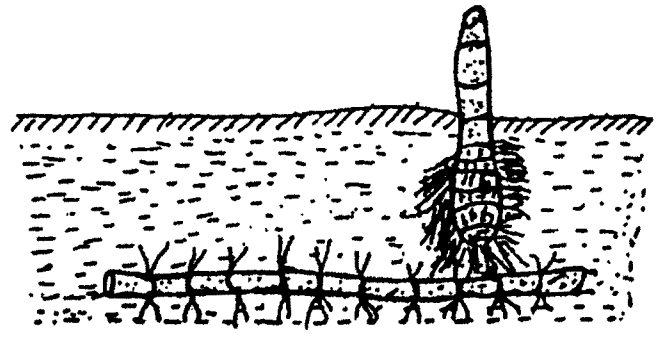
வேர் மற்றும் ரைசோமுடன் கூடிய மூங்கில் கழி

மண்ணில் ஆழம் – 30 செ.மீ.

ரைசோமின் நீளம் – 60 செ.மீ.

6.3 வேர் மற்றும் ரைசோமுடன் கூடிய கிளைகளற்ற மூங்கில் கழி :

இம்முறையில் மூங்கில் கழியானது 30 செ.மீ. உயரம் உள்ளதாக இருக்க வேண்டும். கிளைகளற்றதாகவும் இருக்கும். மேலே விவரித்த மற்ற முறைகள் இதற்கும் பொருந்தும். (வரைபடம்-8).



வரைபடம்-8

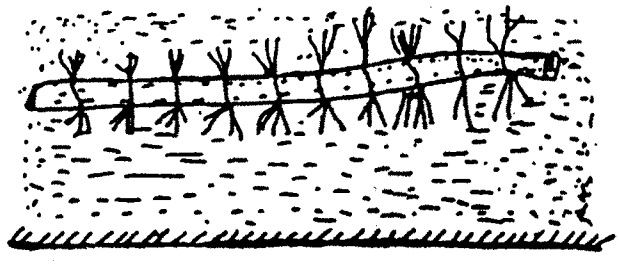
வேர் மற்றும் ரைசோமுடன் கூடிய கிளைகளற்ற மூங்கில்

மண்ணில் ஆழம் – 30 செ.மீ.

ரைசோமின் நீளம் – 50 செ.மீ.

6.4 ரைசோமை வேருடன் நடுதல் :

இம்முறையில் 50-60 செ.மீ. நீளமும், 10-15 கணுக்களும் கொண்ட வேருடன் கூடிய ரைசோமை பயன்படுத்தலாம். 2-3 ஆண்டுகள் வயதுடைய ரைசோம்கள் ஏற்றது. 5 ஆண்டுகளுக்கு மேற்பட்ட ரைசோம்களை முற்றிலுமாக தவிர்க்க வேண்டும். நெடுந்தொலைவு கொண்டு சென்று நடுவதற்கு இம்முறை மிகவும ஏற்றது. ரைசோமிலுள்ள மண்ணை நீரால் சுத்தமாக நீக்கி விட்டு, ஸ்பேக்னம் என்ற பாசி வகையை, வினைல் காகிதத்தைக் கொண்டு சுற்றி பாதுகாப்பாக வைக்க வேண்டும். பொதுவாக இந்த முறையில் ரைசோமை 20 செ.மீ. ஆழத்தில் நட வேண்டும். (வரைபடம்-9). இந்த வகையானது ஒருமுக வளர்ச்சியுள்ள மூங்கிலில் அதிகமாகப் பின்பற்றப்படுகிறது. (படம்-9)



வரைபடம்-9

ரைசோமை வேருடன் நடுதல்

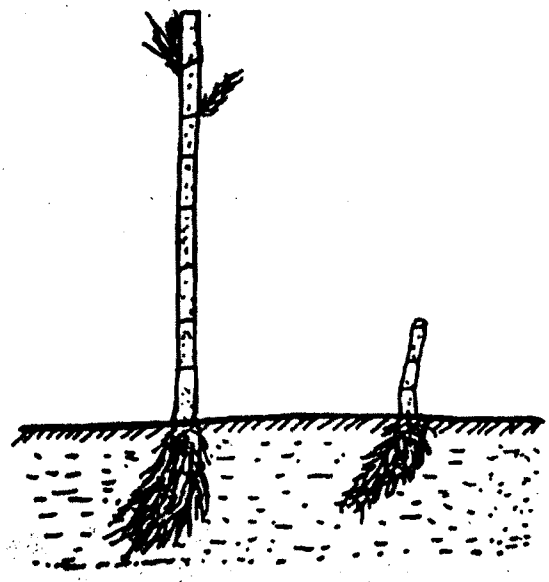
மண்ணில் ஆழம் – 30 செ.மீ.

ரைசோமின் நீளம் – 50 செ.மீ.

9. வேருடன் கூடிய ரைசோம்கள்

6.5 துளிர்விடக்கூடிய ஒரு வருட மூங்கிலை நடுதல் :

இம்முறையில் பன்முக வளர்ச்சியுள்ள மூங்கில் வகையில் பெருமளவு பயன்படுத்தப்பட்டு, வெற்றியும் காணப்பட்டுள்ளது. ஒரு வருட மூங்கில், ரைசோமுடன் கவனமாக நீக்க வேண்டும். மூங்கில் கழியின் உயரம் 30லிருந்து 50 செ.மீ. இருக்க வேண்டும். ரைசோமின் உயிர்தன்மையையும், நடக்கூடிய பருவத்தையும் கொண்டே இம்முறையில் பலன் கிடைக்கும். (வரைபடம்-10).



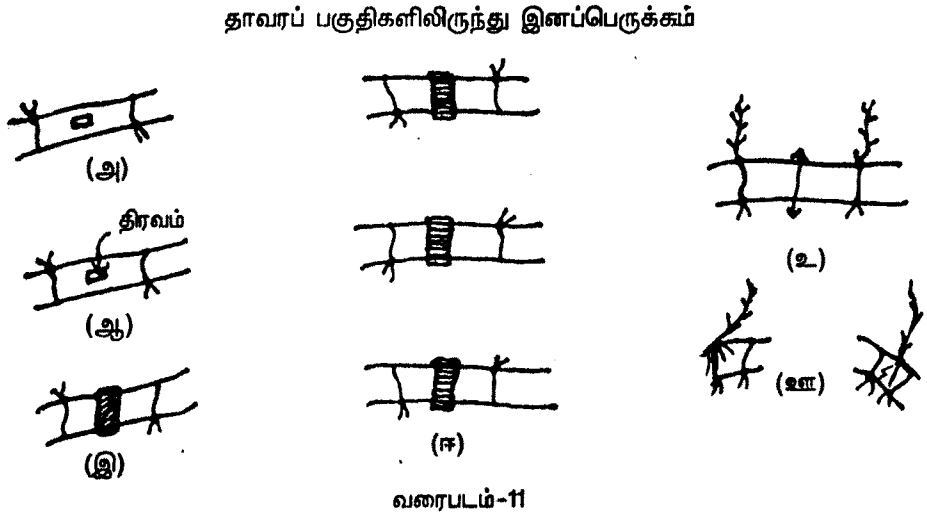
வரைபடம்-10
துளிர் விடக்கூடிய ஒரு வருட மூங்கிலை நடுதல்

6.6 மூங்கிலை பல துண்டுகளாக வெட்டி நடுதல் :

இம்முறை பெருமளவு பயன்படுத்தப்படுகிறது. நடக்கூடிய மூங்கிலின் வயது முக்கிய பங்கு வகிக்கிறது. பொதுவாக இரண்டு வருட மூங்கிலும், இளவேனில் காலமும் மிகவும் ஏற்றது. கேரளாவிலுள்ள வனவியல் ஆராய்ச்சி நிறுவனம், வெட்டப்பட்ட மூங்கில் துண்டுகளை நடுவதற்கு சில வழிமுறைகளை ஏற்படுத்தியுள்ளது. இம்முறையில் வெட்டப்பட்ட மூங்கில் துண்டுகளை வளர்ச்சி ஹார்மோன்களைக் கொண்டு, வேர் விடச் செய்யப்படுகிறது. இம்முறை, ***பாம்பூசா பேம்போஸ், பா. பல்கோவா, பா. பாலிமார்பா, பா. வென்டிரிகோசா, பா. வல்காரிஸ், டென்ரோகேலமஸ் பிரான்டிஸ்சி, டெ. ஹேமில்டோனியே, அக்லன்ட்ரா ஸ்கிரிப்டோரியா*** மற்றும் ***அ. டிரவன்கேரிகா*** போன்ற சிற்றினங்களில் ஆய்வு செய்யப்பட்டு, நல்ல பலன்களும் பெறப்பட்டுள்ளன.

6.6.1 மூங்கில் துண்டுகளை நடுவதற்கு தயார் செய்தல் :

இரண்டு (அ) மூன்று வயதுடைய தாய் மூங்கிலில் இருந்து, கணுப் பகுதியை எடுக்கும்போது, ஒவ்வொன்றிற்கும் முதல் இரண்டு கணுக்களுக்கு மேலேதான் வெட்ட வேண்டும். இரண்டு, இரண்டு கணுக்களை உடைய தண்டுப் பகுதிகளை வெட்டி எடுத்துக் கொள்ள வேண்டும். பூக்கள் உள்ள தண்டுகளும், பூக்கும் என எதிர்பார்க்கப்படும் தண்டுகளும் தவிர்க்கப்படலாம். ஏனெனில் இவை உடனடியாகப் பூத்து பின்பு கன்று மடிந்து விடும். இலைகளை (வரைபடம்-11) படத்தில் உள்ளவாறு கணுக்களுக்கு சேதம் விளைவிக்காமல் வெட்டி எடுத்து விடவும். வெட்டி எடுத்த தண்டுகளை உடனடியாக எடுத்துச் செல்லமுடியாத மற்ற காரணம் இருப்பின், வெட்டிய தண்டுகளை ஈரப்பதம் உளள மரத்தூளுக்கு நடுவில் வைத்துப் பாதுகாத்து பின்பு எடுத்துச் செல்லலாம். பின்பு இரண்டு கணுக்களுக்கு மத்தியில், படத்தில் காணப்படுவது போல் கூரிய கத்தியால் வெட்டிக் கொள்ளவும். வெட்டும்போது மூங்கில் வெடித்து விடாமல் பார்த்துக் கொள்வது மிகவும் முக்கியமாகும்.



வரைபடம்-11

(அ) நடுப்பகுதியில் துளையிடப்பட்ட மூங்கில் தண்டு

(ஆ) துளையிடப்பட்ட பகுதி மூலம் திரவம் ஊற்றப்படுகிறது

(இ) பாலித்தீன் காகிதத்தால் இறுக்கிக் கட்டப்பட்ட தண்டு

(ஈ) நாற்றங்காலில் பதியம் இடுதல்

(உ) வேருடன் கூடிய நாற்று

(ஊ) இரண்டாகப் பிரிக்கப்பட்ட நாற்று

இதற்கிடையில் 10 கிராம் நாப்தலின் அசிடிக் அமிலம் எடுத்து, 250 மில்லி லிட்டர் எத்தில் ஆல்கஹாலில் நன்றாகக் கரைத்துக் கொண்டு, சுத்தமான பெரிய கொள்கலனில் விட்டு 100 லிட்டர் வருமாறு தண்ணீர் ஊற்றி நன்கு கலந்து கொள்ளவும். இறுதியாகக் கிடைக்கும் திரவக் கரைசல் 1000 தண்டுகளுக்குப் போதுமானதாகும்.

ஒவ்வொரு தண்டிற்கும் 100 மில்லி லிட்டர் வீதம் சிறிய வாய் உள்ள பாட்டில் மூலமாக வீணாகாமல் தண்டின் வெட்டிய பகுதியில் ஊற்ற வேண்டும். ஊற்றிய பின்பு 60 செ.மீ. நீளமும், 6 செ.மீ. அகலமும் உள்ள பிளாஸ்டிக் காகிதத்தால், துளைப் பகுதியை இறுக்கமாக, ஊற்றப்பட்ட கரைசல் வெளியே வராமல் கட்ட வேண்டும். தண்டுகளை நாற்றாங் காலுக்குக் கொண்டு வந்தவுடன் இம்முறையைக் கையாள வேண்டும்.

6.6.2 நாற்றாங்கால் அமைப்பு :

நாற்றாங்கால் பகுதியில் உள்ள மண்ணை நன்றாகப் பண்படுத்தி மண் மற்றும் மணல் 3:1 என்ற விகிதத்தில் தயார் செய்து கொள்ள வேண்டும். பாத்திகள் 10 மீட்டர் X 1 மீட்டர் அளவில் இருக்கலாம். நாற்றாங்காலை ஒரு வாரத்திற்கு முன்பே தயார் செய்து உலர வைத்து கரையான் மற்றும் பூச்சிகளைத் தவிர்க்க பூச்சிக்கொல்லி மருந்து (ஆல்டிரின்), காளான் கொல்லி (பாவிஸ்டின்) தெளிக்க வேண்டும். ஒவ்வொரு பாத்திக்கும் 40 லிட்டர் ஆல்டிரிலும் (0.015 சதம்), 30 லிட்டர் பாவிஸ்டின் (0.05 சதம்) தண்ணீரில் கலந்து தெளிக்கவும்.

6.6.3 நாற்று நடுதலும், பராமரிப்பும் :

தண்டுகளை கிடைநிலையில் துளை செய்யப்பட்ட பகுதி மேல் நோக்கியவாறு மண்ணில் பதிக்க வேண்டும். 50-60 தண்டுப் பகுதிகள் ஒரு பாத்தியில் வருமாறு அமைக்க வேண்டும். பின்பு தண்டுகளின் மேல்பாகம் தெரியும்படி மிதமாக மண்தூவி விடவும். இப்பாத்திகளின் மேல் கூரை அமைப்பது மிகவும் அவசியம். ஏனெனில் சூரியக் கதிர்கள் நாற்றுக்களை

நேரடியாகத் தாக்காமல் தண்டுகள் காக்கப்படுவது மிகவும் முக்கியம். இந்தக் கூரையை மழைக்காலம் ஆரம்பிக்கும் முன்பு எடுத்துவிட வேண்டும். இந்த நாற்றாங்காலில் காலை, மாலை இரு நேரங்களிலும் தண்ணீர் தெளிக்க வேண்டும். தண்ணீர் தேங்காமல் பார்த்துக் கொள்வது மிகவும் அவசியம். ஜூன், ஜூலை மாதங்களில் முளைத்த தண்டுகளை வேர்ப்பகுதிகளோடு தோண்டி எடுத்து இரண்டு கணுக்களுக்கும் நடுவில் மிகக் கவனமாக வெட்டி, இரண்டு தனித்தனிக் கன்றுகளாகவும் நிலத்தில் நடலாம்.

முளைத்த தண்டுகளை 5 X 5 மீட்டர் இடைவெளியில் நட வேண்டும். தினமும் காலை, மாலை வேளைகளில் நீர் பாய்ச்ச வேண்டும். சுமார் ஆறு மாதங்களுக்குப் பின்னர் 15 நாட்களுக்கு ஒருமுறை நீர் பாய்ச்சுதல் போதுமானது. மண்ணில் ஈரப்பதம் இருப்பது அதிக எண்ணிக்கையில் கழிகளைத் தோற்றுவிக்கும். முதல் ஆண்டில் மூன்று முறையும், பின் அடுத்த இரண்டு ஆண்டுகளுக்கு இருமுறை என்றும் களை நீக்கி மண்ணைக் கொத்திவிட வேண்டும். வறண்டு வீட்ட நாற்றுக்களை நீக்கிவிட்டு புது நாற்றுக்களை நட வேண்டும். மூங்கில் நாற்று நட்ட பின்பு கால்நடை மேயாமல் இருக்க வேலி போடுவது மிக முக்கியம்.

6.7 கிளைகளை நடுதல் :

இந்த முறையில் நல்ல முறையில் ஆரோக்கியமாகவும் (healthy) வீரிய முறையிலும் (vigour) உள்ள மூங்கிலிலிருந்து கிளைகளை கூர்மையான கத்தியால் வெட்டி எடுக்க வேண்டும். கிளைகளிலுள்ள இலைகளையும் நீக்கிவிட்டு இரண்டு, இரண்டு கணுக்களுடைய கிளைகளை தயார் செய்து கொள்ள வேண்டும். இவ்வாறு தயார் செய்யப்பட்ட கிளைகளை உடனடியாக நாற்றாங்காலுக்குக் கொண்டு செல்லுதல் அவசியம். நாற்றாங்காலில் கணுக்களில் வேரின் வளர்ச்சியைத் தூண்டச் செய்யும் இயற்கைக் கலவையை தயார் செய்ய வேண்டும். இந்த இயற்கை கலவையானது அரிசி தவிடு, மாட்டுச் சாணம், கரித்தூள் மற்றும் மணல்

இவற்றை சம அளவில் கலந்து தயார் செய்யப்பட்டதாகும். இந்த கலவையை 45 செ.மீ. உயரமுடைய பாலிதீன் பைகளில் நிரப்ப வேண்டும். இந்த பைகளில் ஏற்கனவே தயார் செய்யப்பட்ட கிளைகளை நட வேண்டும். இவ்வாறு நட்ட கிளைகளை மேல்கூரை அமைத்து சூரிய ஒளியிலிருந்து பாதுகாக்க வேண்டும். தினமும் காலை, மாலை வேளைகளில் நீர் பாய்ச்சுவது அவசியம். இவ்வாறு பராமரிக்கப்பட்ட கிளைகளில் 20-30 நாட்களுக்குள் கணுக்களில் வேர்துளிகள் தோன்ற துவங்கிவிடும். இந்த வேர்களானது, பின்னர் ரைசோமாக வளர்ச்சி யடைகிறது. இவ்வாறு வளர்ச்சி பெற்ற கிளைகளை ஆகஸ்ட் மாதங்களில் மண்ணில் நடலாம். இம்முறையில் கீழ்க்காணும் தன்மைகள் உண்டு.

1. மிகவும் எளிதான முறையாகவும், விவசாயிகள் சுலபமாக கையாளும் வகையிலும் உள்ளது.
2. விலை மதிப்பு மிக்க வேதிவினைப் பொருள்கள் தேவையில்லை. .
3. ஒரு மூங்கில் கழியிலிருந்து, ஏராளமான எண்ணிக்கையில் மூங்கில் நாற்றுக்களை எளிதில் பெறலாம்.

6.8 திசு வளர்ப்பு முறை :

மிக அதிகமான எண்ணிக்கையில் மூங்கில் விதைகள் மூலமாகவும், ஏனைய பிற வழிகளிலும் (vegetative propagation) தோற்றுவிப்பது மிகவும் கடினமான ஒன்றாகும். மூங்கில் மலர்வதின் கால இடைவெளி அதிகமாக இருப்பதாலும், மிகக் குறைந்த நாட்களே உயிர் தன்மை (viability) கொண்ட விதைகளாக இருப்பதும் காரணமாக உள்ளது. ஏனைய பிற வழிகளில் நாற்றுக்களை தோற்றுவித்தாலும், ஒரு தாய் மூங்கிலிலிருந்து பெறப்பட்ட நாற்றுக்களானது, எந்த நாட்டில் எந்த இடத்தில் இருந்தாலும் ஒரே சமயத்தில் மலர்ந்து, மடிந்து போவது மூங்கிலின் சிறப்பு பண்பாக உள்ளது. இந்த தருணத்தில் திசு வளர்ப்பின் மூலம் பெறப்பட்ட நாற்றுக்கள் மிக முக்கியமான பங்கு வகிக்கிறது.

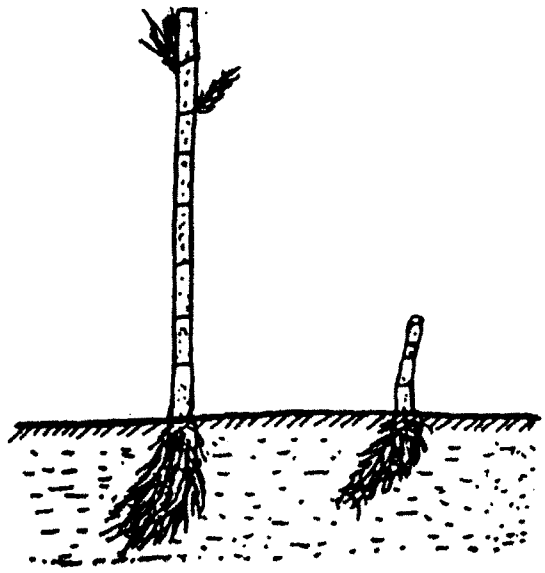
தாவரங்களிலுள்ள ஒவ்வொரு செல்லும், ஒரு புதிய தாவரங்களைத் தோற்றுவிக்கும் தன்மையுடையது என்பது திசு வளர்ப்பின் மிக முக்கிய கோட்பாடாக உள்ளது. மூங்கில் திசு வளர்ப்பக்கு பல்வேறு வழிமுறைகள் தெரிவிக்கப்பட்டன. அந்த அனைத்து வழிமுறைகளையும், பரிசோதனை செய்து ஒரு சிறந்த வழிமுறையை (protocol) கோயமுத்தூரிலுள்ள வன மரபியல் மற்றும் மர பெருக்க மையத்தைச் சார்ந்த தாவர உயிர்நுட்ப பிரிவு வெளியிட்டுள்ளது. இம்மையத்தில் பெரு மூங்கில், சிறு மூங்கில், உணவு வகை மூங்கில் போன்ற பல வகையான மூங்கில்களுக்கு திசு வளர்ப்பு முறையில் நாற்றுக்களை உற்பத்தி செய்யும் வழிமுறைகள் தெரிவிக்கப்பட்டுள்ளன.

6.8.1 கணு மொட்டுக்களை தேர்ந்தெடுத்தல்

தேர்ந்தெடுக்கப்பட்ட வீரியமுள்ள மூங்கிலில் இருந்து ஒரு கணு மொட்டுகளையோ அல்லது மூங்கில் நாற்றுக்களில் உள்ள கிளை மொட்டுகளையோ திசு வளர்ப்பு முறைக்கு மூலப் பொருளாக எடுக்க வேண்டும். எந்த தருணத்தில் மொட்டுக்களை எடுக்க வேண்டும் என்பதில் மிகுந்த கவனமாக இருக்க வேண்டும். மொட்டுக்கள் உருவாகும் போதே அதனை எடுக்க வேண்டும்.

6.8.2 மொட்டுக்களை சுத்தம் செய்தல் :

மொட்டுக்களை அதிலுள்ள தூசிகள், நுண்ணுயிர்கள் போன்றவற்றிலிருந்து சுத்தம் செய்வது அவசியம். முதலில் நல்ல நீரில் சுத்தமாகக் கழுவ வேண்டும். பின் 0.1 சதம் சோடியம் ஹைபோகுளோரைடில் 5 நிமிடங்கள் கழுவிய பின், சுத்திகரிக்கப்பட்ட நீரில் இந்த அமிலம் முழுவதும் நீங்கும் வண்ணம் கழுவ வேண்டும். அதன்பின் 0.1 சதம் மெர்குரிக் குளோரைட்டில் 5 நிமிடங்கள் கழுவ வேண்டும். பின் அனைத்து அமிலங்களும் நீங்கும் வண்ணம், சுத்திகரிக்கப்பட்ட நீரில் நன்றாகக் கழுவி, சுத்தம் செய்ய வேண்டும். இவையனைத்தும் மிகவும் சுத்தமான இடத்தில், ஆய்வகத்தில் செய்ய



வரைபடம்-10
துளிர் விடக்கூடிய ஒரு வருட மூங்கிலை நடுதல்

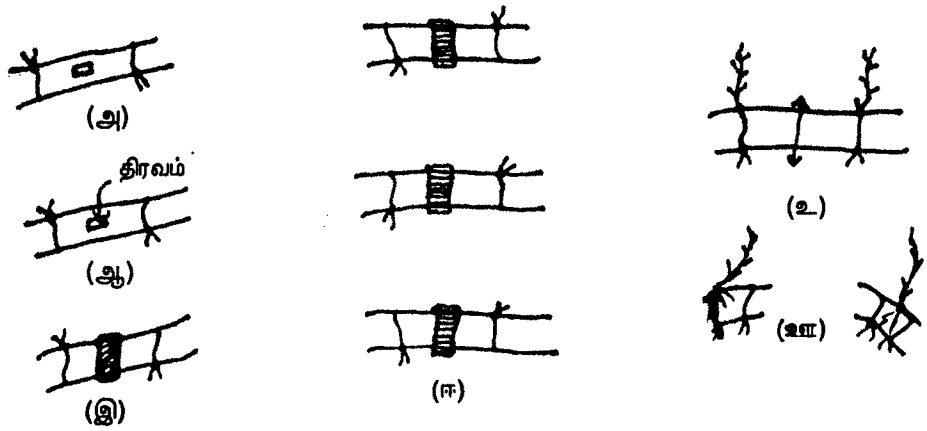
6.6 மூங்கிலை பல துண்டுகளாக வெட்டி நடுதல் :

இம்முறை பெருமளவு பயன்படுத்தப்படுகிறது. நடக்கூடிய மூங்கிலின் வயது முக்கிய பங்கு வகிக்கிறது. பொதுவாக இரண்டு வருட மூங்கிலும், இளவேனில் காலமும் மிகவும் ஏற்றது. கேரளாவிலுள்ள வனவியல் ஆராய்ச்சி நிறுவனம், வெட்டப்பட்ட மூங்கில் துண்டுகளை நடுவதற்கு சில வழிமுறைகளை ஏற்படுத்தியுள்ளது. இம்முறையில் வெட்டப்பட்ட மூங்கில் துண்டுகளை வளர்ச்சி ஹார்மோன்களைக் கொண்டு, வேர் விடச் செய்யப்படுகிறது. இம்முறை, ***பாம்பூசா பேம்போஸ், பா. பல்கோவா, பா. பாலிமார்பா, பா. வென்டிகோசா, பா. வல்காரிஸ், டென்ரோகேலமஸ் பிரான்டிஸ்சி, டெ. ஹேமில்டோனியே, அக்லன்ட்ரா ஸ்கிரிப்டோரியா*** மற்றும் ***அ. டிரவன்கேரிகா*** போன்ற சிற்றினங்களில் ஆய்வு செய்யப்பட்டு, நல்ல பலன்களும் பெறப்பட்டுள்ளன.

6.6.1 மூங்கில் துண்டுகளை நடுவதற்கு தயார் செய்தல் :

இரண்டு (அ) மூன்று வயதுடைய தாய் மூங்கிலில் இருந்து, கணுப் பகுதியை எடுக்கும்போது, ஒவ்வொன்றிற்கும் முதல் இரண்டு கணுக்களுக்கு மேலேதான் வெட்ட வேண்டும். இரண்டு, இரண்டு கணுக்களை உடைய தண்டுப் பகுதிகளை வெட்டி எடுத்துக் கொள்ள வேண்டும். பூக்கள் உள்ள தண்டுகளும், பூக்கும் என எதிர்பார்க்கப்படும் தண்டுகளும் தவிர்க்கப்படலாம். ஏனெனில் இவை உடனடியாகப் பூத்து பின்பு கன்று மடிந்து விடும். இலைகளை (வரைபடம்-11) படத்தில் உள்ளவாறு கணுக்களுக்கு சேதம் விளைவிக்காமல் வெட்டி எடுத்து விடவும். வெட்டி எடுத்த தண்டுகளை உடனடியாக எடுத்துச் செல்லமுடியாத மற்ற காரணம் இருப்பின், வெட்டிய தண்டுகளை ஈரப்பதம் உள்ள மரத்தூளுக்கு நடுவில் வைத்துப் பாதுகாத்து பின்பு எடுத்துச் செல்லலாம். பின்பு இரண்டு கணுக்களுக்கு மத்தியில், படத்தில் காணப்படுவது போல் கூரிய கத்தியால் வெட்டிக் கொள்ளவும். வெட்டும்போது மூங்கில் வெடித்து விடாமல் பார்த்துக் கொள்வது மிகவும் முக்கியமாகும்.

தாவரப் பகுதிகளிலிருந்து இனப்பெருக்கம்



வரைபடம்-11

(அ) நடுப்பகுதியில் துளையிடப்பட்ட மூங்கில் தண்டு

(ஆ) துளையிடப்பட்ட பகுதி மூலம் திரவம் ஊற்றப்படுகிறது

(இ) பாலித்தீன் காகிதத்தால் இறுக்கிக் கட்டப்பட்ட தண்டு

(ஈ) நாற்றங்காலில் பதியம் இடுதல்

(உ) வேருடன் கூடிய நாற்று

(ஊ) இரண்டாகப் பிரிக்கப்பட்ட நாற்று

இதற்கிடையில் 10 கிராம் நாப்தலின் அசிடிக் அமிலம் எடுத்து, 250 மில்லி லிட்டர் எத்தில் ஆல்கஹாலில் நன்றாகக் கரைத்துக் கொண்டு, சுத்தமான பெரிய கொள்கலனில் விட்டு 100 லிட்டர் வருமாறு தண்ணீர் ஊற்றி நன்கு கலந்து கொள்ளவும். இறுதியாகக் கிடைக்கும் திரவக் கரைசல் 1000 தண்டுகளுக்குப் போதுமானதாகும்.

ஒவ்வொரு தண்டிற்கும் 100 மில்லி லிட்டர் வீதம் சிறிய வாய் உள்ள பாட்டில் மூலமாக வீணாகாமல் தண்டின் வெட்டிய பகுதியில் ஊற்ற வேண்டும். ஊற்றிய பின்பு 60 செ.மீ. நீளமும், 6 செ.மீ. அகலமும் உள்ள பிளாஸ்டிக் காகிதத்தால், துளைப் பகுதியை இறுக்கமாக, ஊற்றப்பட்ட கரைசல் வெளியே வராமல் கட்ட வேண்டும். தண்டுகளை நாற்றாங் காலுக்குக் கொண்டு வந்தவுடன் இம்முறையைக் கையாள வேண்டும்.

6.6.2 நாற்றாங்கால் அமைப்பு :

நாற்றாங்கால் பகுதியில் உள்ள மண்ணை நன்றாகப் பண்படுத்தி மண் மற்றும் மணல் 3:1 என்ற விகிதத்தில் தயார் செய்து கொள்ள வேண்டும். பாத்திகள் 10 மீட்டர் X 1 மீட்டர் அளவில் இருக்கலாம். நாற்றாங்காலை ஒரு வாரத்திற்கு முன்பே தயார் செய்து உலர வைத்து கரையான் மற்றும் பூச்சிகளைத் தவிர்க்க பூச்சிக்கொல்லி மருந்து (ஆல்டிரின்), காளான் கொல்லி (பாவிஸ்டின்) தெளிக்க வேண்டும். ஒவ்வொரு பாத்திக்கும் 40 லிட்டர் ஆல்டிரிலும் (0.015 சதம்), 30 லிட்டர் பாவிஸ்டின் (0.05 சதம்) தண்ணீரில் கலந்து தெளிக்கவும்.

6.6.3 நாற்று நடுதலும், பராமரிப்பும் :

தண்டுகளை கிடைநிலையில் துளை செய்யப்பட்ட பகுதி மேல் நோக்கியவாறு மண்ணில் பதிக்க வேண்டும். 50-60 தண்டுப் பகுதிகள் ஒரு பாத்தியில் வருமாறு அமைக்க வேண்டும். பின்பு தண்டுகளின் மேல்பாகம் தெரியும்படி மிதமாக மண்தூவி விடவும். இப்பாத்திகளின் மேல் கூரை அமைப்பது மிகவும் அவசியம். ஏனெனில் சூரியக் கதிர்கள் நாற்றுக்களை

நேரடியாகத் தாக்காமல் தண்டுகள் காக்கப்படுவது மிகவும் முக்கியம். இந்தக் கூரையை மழைக்காலம் ஆரம்பிக்கும் முன்பு எடுத்துவிட வேண்டும். இந்த நாற்றாங்காலில் காலை, மாலை இரு நேரங்களிலும் தண்ணீர் தெளிக்க வேண்டும். தண்ணீர் தேங்காமல் பார்த்துக் கொள்வது மிகவும் அவசியம். ஜூன், ஜூலை மாதங்களில் முளைத்த தண்டுகளை வேர்ப்பகுதிகளோடு தோண்டி எடுத்து இரண்டு கணுக்களுக்கும் நடுவில் மிகக் கவனமாக வெட்டி, இரண்டு தனித்தனிக் கன்றுகளாகவும் நிலத்தில் நடலாம்.

முளைத்த தண்டுகளை 5 X 5 மீட்டர் இடைவெளியில் நட வேண்டும். தினமும் காலை, மாலை வேளைகளில் நீர் பாய்ச்ச வேண்டும். சுமார் ஆறு மாதங்களுக்குப் பின்னர் 15 நாட்களுக்கு ஒருமுறை நீர் பாய்ச்சுதல் போதுமானது. மண்ணில் ஈரப்பதம் இருப்பது அதிக எண்ணிக்கையில் கழிகளைத் தோற்றுவிக்கும். முதல் ஆண்டில் மூன்று முறையும், பின் அடுத்த இரண்டு ஆண்டுகளுக்கு இருமுறை என்றும் களை நீக்கி மண்ணைக் கொத்திவிட வேண்டும். வறண்டு விட்ட நாற்றுக்களை நீக்கிவிட்டு புது நாற்றுக்களை நட வேண்டும். மூங்கில் நாற்று நட்ட பின்பு கால்நடை மேயாமல் இருக்க வேலி போடுவது மிக முக்கியம்.

6.7 கிளைகளை நடுதல் :

இந்த முறையில் நல்ல முறையில் ஆரோக்கியமாகவும் (healthy) வீரிய முறையிலும் (vigour) உள்ள மூங்கிலிலிருந்து கிளைகளை கூர்மையான கத்தியால் வெட்டி எடுக்க வேண்டும். கிளைகளிலுள்ள இலைகளையும் நீக்கிவிட்டு இரண்டு, இரண்டு கணுக்களுடைய கிளைகளை தயார் செய்து கொள்ள வேண்டும். இவ்வாறு தயார் செய்யப்பட்ட கிளைகளை உடனடியாக நாற்றாங்காலுக்குக் கொண்டு செல்லுதல் அவசியம். நாற்றாங்காலில் கணுக்களில் வேரின் வளர்ச்சியைத் தூண்டச் செய்யும் இயற்கைக் கலவையை தயார் செய்ய வேண்டும். இந்த இயற்கை கலவையானது அரிசி தவிடு, மாட்டுச் சாணம், கரித்தூள் மற்றும் மணல்

இவற்றை சம அளவில் கலந்து தயார் செய்யப்பட்டதாகும். இந்த கலவையை 45 செ.மீ. உயரமுடைய பாலிதீன் பைகளில் நிரப்ப வேண்டும். இந்த பைகளில் ஏற்கனவே தயார் செய்யப்பட்ட கிளைகளை நட வேண்டும். இவ்வாறு நட்ட கிளைகளை மேல்கூரை அமைத்து சூரிய ஒளியிலிருந்து பாதுகாக்க வேண்டும். தினமும் காலை, மாலை வேளைகளில் நீர் பாய்ச்சுவது அவசியம். இவ்வாறு பராமரிக்கப்பட்ட கிளைகளில் 20-30 நாட்களுக்குள் கணுக்களில் வேர்துளிகள் தோன்ற துவங்கிவிடும். இந்த வேர்களானது, பின்னர் ரைசோமாக வளர்ச்சி யடைகிறது. இவ்வாறு வளர்ச்சி பெற்ற கிளைகளை ஆகஸ்ட் மாதங்களில் மண்ணில் நடலாம். இம்முறையில் கீழ்க்காணும் நன்மைகள் உண்டு.

1. மிகவும் எளிதான முறையாகவும், விவசாயிகள் சுலபமாக கையாளும் வகையிலும் உள்ளது.
2. விலை மதிப்பு மிக்க வேதிவினைப் பொருள்கள் தேவையில்லை.
3. ஒரு மூங்கில் கழியிலிருந்து, ஏராளமான எண்ணிக்கையில் மூங்கில் நாற்றுக்களை எளிதில் பெறலாம்.

6.8 திசு வளர்ப்பு முறை :

மிக அதிகமான எண்ணிக்கையில் மூங்கில் விதைகள் மூலமாகவும், ஏனைய பிற வழிகளிலும் (vegetative propagation) தோற்றுவிப்பது மிகவும் கடினமான ஒன்றாகும். மூங்கில் மலர்வதின் கால இடைவெளி அதிகமாக இருப்பதாலும், மிகக் குறைந்த நாட்களே உயிர் தன்மை (viability) கொண்ட விதைகளாக இருப்பதும் காரணமாக உள்ளது. ஏனைய பிற வழிகளில் நாற்றுக்களை தோற்றுவித்தாலும், ஒரு தாய் மூங்கிலிலிருந்து பெறப்பட்ட நாற்றுக்களானது, எந்த நாட்டில் எந்த இடத்தில் இருந்தாலும் ஒரே சமயத்தில் மலர்ந்து, மடிந்து போவது மூங்கிலின் சிறப்பு பண்பாக உள்ளது. இந்த தருணத்தில் திசு வளர்ப்பின் மூலம் பெறப்பட்ட நாற்றுக்கள் மிக முக்கியமான பங்கு வகிக்கிறது.

தாவரங்களிலுள்ள ஒவ்வொரு செல்லும், ஒரு புதிய தாவரங்களைத் தோற்றுவிக்கும் தன்மையுடையது என்பது திசு வளர்ப்பின் மிக முக்கிய கோட்பாடாக உள்ளது. மூங்கில் திசு வளர்ப்பக்கு பல்வேறு வழிமுறைகள் தெரிவிக்கப்பட்டன. அந்த அனைத்து வழிமுறைகளையும், பரிசோதனை செய்து ஒரு சிறந்த வழிமுறையை (protocol) கோயமுத்தூரிலுள்ள வன மரபியல் மற்றும் மர பெருக்க மையத்தைச் சார்ந்த தாவர உயிர்நுட்ப பிரிவு வெளியிட்டுள்ளது. இம்மையத்தில் பெரு மூங்கில், சிறு மூங்கில், உணவு வகை மூங்கில் போன்ற பல வகையான மூங்கில்களுக்கு திசு வளர்ப்பு முறையில் நாற்றுக்களை உற்பத்தி செய்யும் வழிமுறைகள் தெரிவிக்கப்பட்டுள்ளன.

6.8.1 கணு மொட்டுக்களை தேர்ந்தெடுத்தல்

தேர்ந்தெடுக்கப்பட்ட வீரியமுள்ள மூங்கிலில் இருந்து ஒரு கணு மொட்டுகளையோ அல்லது மூங்கில் நாற்றுக்களில் உள்ள கிளை மொட்டுகளையோ திசு வளர்ப்பு முறைக்கு மூலப் பொருளாக எடுக்க வேண்டும். எந்த தருணத்தில் மொட்டுக்களை எடுக்க வேண்டும் என்பதில் மிகுந்த கவனமாக இருக்க வேண்டும். மொட்டுக்கள் உருவாகும் போதே அதனை எடுக்க வேண்டும்.

6.8.2 மொட்டுக்களை சுத்தம் செய்தல் :

மொட்டுக்களை அதிலுள்ள தூசிகள், நுண்ணுயிர்கள் போன்றவற்றிலிருந்து சுத்தம் செய்வது அவசியம். முதலில் நல்ல நீரில் சுத்தமாகக் கழுவ வேண்டும். பின் 0.1 சதம் சோடியம் ஹைபோகுளோரைடில் 5 நிமிடங்கள் கழுவிய பின், சுத்திகரிக்கப்பட்ட நீரில் இந்த அமிலம் முழுவதும் நீங்கும் வண்ணம் கழுவ வேண்டும். அதன்பின் 0.1 சதம் மெர்குரிக் குளோரைட்டில் 5 நிமிடங்கள் கழுவ வேண்டும். பின் அனைத்து அமிலங்களும் நீங்கும் வண்ணம், சுத்திகரிக்கப்பட்ட நீரில் நன்றாகக் கழுவி, சுத்தம் செய்ய வேண்டும். இவையனைத்தும் மிகவும் சுத்தமான இடத்தில், ஆய்வகத்தில் செய்ய

வேண்டும். இவ்வாறு சுத்தம் செய்யப்பட்ட மொட்டுக்களை முராசிகே மற்றும் ஸ்கூக் கலவையில், 0.5 மி.கி. / லிட்டர் பென்சைல் அமினோ பியூரின் கலந்து வைக்க வேண்டும். இந்த திசு வளர்ப்பு கலவையை 12 மணி நேரம் இருட்டிலும், 12 மணி நேரம் வெளிச்சத்திலும் வைக்க வேண்டும்.

6.8.3 திசு வளர்ப்பு கலவையை தயார் செய்தல் :

திசு வளர்ப்பு கலவையை பின்வரும் முறையில் தயார் செய்யலாம். கீழே குறிப்பிட்டுள்ள வேதிப் பொருட்களை மிகச் சரியான முறையில கொடுக்கப்பட்ட அளவுகளில், எடை செய்து எடுத்து, 1 லிட்டர் சுத்திகரிக்கப்பட்ட நீரில் நன்றாகக் கலக்க வேண்டும். இவ்வாறு தயார் செய்யப்பட்ட கலவை, சரியான குடுவையில் வைத்து தகுந்த முறையில் அடைத்தபின் ஆட்டோகுளோவ் எனப்படும் சாதனத்தில் வைத்து சுத்தப்படுத்த வேண்டும். பின் இதனை உபயோகிக்க வேண்டும்.

வேதிப்பொருட்கள்	**மில்லி கிராம் / லிட்டர்**
அமோனியம் நைட்ரேட்	1650.00
பொட்டாசியம் நைட்ரேட்	1900.00
கால்சியம் குளோரைட்	440.00
மெக்னீசியம் சல்பேட்	370.00
பொட்டாசியம் டை ஹைட்ரஜன் பாஸ்பேட்	170.00
பொட்டாசியம் அயோடைட்	0.83
போரிக் அமிலம்	6.20
மென்கனீசு சல்பேட்	22.30
ஜிங் சல்பேட்	8.60
சோடியம் மாலிப்டேட்	0.25
காப்பர் சல்பேட்	0.025
கோபால்ட் குளோரைட்	0.025

பெர்ரஸ் சல்பேட்	27.84
எத்திலின் டைஅமைன் டெட்ரா அசிடிக் அமிலம்	37.30
மையோஇனோசிடால்	100.00
நிகோடிக் அமிலம்	0.50
பைரிடாக்சின்	0.50
தைமின்	0.10
கிளைசின்	2.00
சுக்ரோஸ்	30,000.00
பென்சைல் அமினோ பியூரின்	0.50

6.8.4. திசு வளர்ச்சி :

திசு வளர்ப்பு கலவையில் சுத்தம் செய்யப்பட்ட மொட்டுக்களை வைத்து, ஆய்வகத்தில் சரியான வெப்பநிலையில் வைக்க வேண்டும். அவ்வாறு வைத்து ஒரு மாதத்தில், மொட்டுக்களிலுள்ள செல்கள் பகுப்படைந்து, சிறு கொழுந்தை (shoot bud) தோற்றுவிக்கிறது. அடுத்த இருபது நாட்களுக்குள், சுமார் 20-30 கொழுந்துகள் தோற்றுவிக்கப் படுகிறது. பின் இவற்றை தனித்தனியே பிரித்து, வெவ்வேறு குடுவைகளில் தலா மூன்று குருத்துக்களை வைத்து பராமரிக்க வேண்டும்.

6.8.5 வேர் விடுதல் :

இவ்வாறு பிரித்து குடுவைகளில் வைக்கப்பட்ட குருத்துக்களானது வேர்விடத் துவங்குகிறது. 90 சதம் மொட்டுக்கள் 0.1 மில்லி கிராம் / லிட்டர் இன்டோல் பியூட்ரிக் அமிலம் சேர்க்கப்பட்ட முராசிகே ஸ்கூக் கலவையில் வேர் விடுகிறது. பின் வேர்க் குருத்துக்கள் பகுப்படைந்து, ரைசோமைத் தோற்றுவிக்கிறது. இந்த ரைசோமுடன் கூடிய மிகச் சிறிய தாவரமானது, 1:1:1 என்ற விகிதத்தில் மணல், மண், வெர்மிகுலேட்

சேர்க்கப்பட்ட கலவையில் எடுத்து நடப்படுகிறது. 0.1 சதம் பாவிஸ்டின் இதன் மீது, பூஞ்சைத் தாக்குதலிலிருந்து பாதுகாக்க தெளிக்கப்படுகிறது. ஒரு மாதத்திற்குப் பின்னர் திசு வளர்ப்பின் மூலம் பெறப்பட்ட இந்த நாற்றானது, மண்ணில் (field) நடப்படுகிறது. (படம்-10)

10. வேருடன் கூடிய ரைசோம்கள்

6.9 பராமரிப்பு முறைகள் :

மூங்கில் தோட்டங்களை அமைப்பதற்கும், பின் பராமரிப்பதற்கும் சில முக்கிய வழிமுறைகள் வருமாறு :

(1) மூங்கில் நாற்றுக்களை, விதை மூலமாகவும் (seeds) இதர வழிகளிலும் (vegetative methods) பெற முடிந்தாலும், பொதுவாக திசு வளர்ப்பன மூலம் பெறப்பட்ட நாற்றுக்களையே பெருமளவு பயன்படுத்தப் பட்டு வருகிறது.

(2) சுமார் 20 செ.மீ. அகலமும், 30 செ.மீ. உயரமும் கொண்ட பாலிதின் பைகளில், மண், மணல், சாணம் மூன்றும் முறையே 2:1:1 என்ற விகிதத்தில் கலந்த கலவையை அடைத்து, அதில் 15 முதல் 20 மூங்கில் நாற்றுக்களை நட வேண்டும். இவ்வாறு நடப்பட்ட

நாற்றுக்களுக்கு காலையும், மாலையும் போதிய அளவு நீர் ஊற்றுதல் அவசியம். நீர் தேங்கி நிற்காமல் பார்த்துக் கொள்ள வேண்டும்.

(3) மூங்கில் நாற்றுகள் நடவு செய்யப்பட்ட பாலிதீன் பைகளுக்கு மேல் கூரை அமைப்பது மிகவும் அவசியம். இதன் மூலம் நாற்றுக்களை சூரிய ஒளியிலிருந்து பாதுகாக்கலாம். சுமார் ஒரு மாத காலம் இதில் வைத்து பாதுகாக்க வேண்டும்.

(4) பின் மூங்கில் நாற்றுக்களை, பாலித்தீன் பைகளிலிருந்து அகற்றி, 45 செ.மீ. X 45 செ.மீ. X 45 செ.மீ. அளவுள்ள குழிகளில் 6 மீட்டர் X 6 மீட்டர் இடைவெளியில் நட வேண்டும் (field transfer). நடுவதற்கு ஒரு வாரம் முன்பாக, குழிகளுக்கு 0.01 சதம் ஆல்ட்ரக்ஸ், 0.05 சதம் பாவிஸ்டின் தெளித்து, பூஞ்சிகள், பூஞ்சாளங்களிலிருந்து பாதுகாக்க வேண்டும்.

(5) நல்ல முறையில் நாற்று வளர்ச்சியை துரிதப்படுத்த, ஒவ்வொரு குழிக்கும் 25 கிராம் 15:15:15 நைட்ரஜன், பாஸ்பரஸ் பொட்டாசியம் கலவையை இட்டு பராமரிக்கப்பட வேண்டும்.

(6) பூச்சிகள், எலிகள், மற்றம் மேயும் விலங்குகளிலிருந்து நாற்றுக்களைப் பாதுகாக்க கம்பி வேலி அமைத்தல் அவசியம்.

(7) பிடுங்கி நடப்பட்ட ஒவ்வொரு நாற்றுக்களிலும் முதலில் நல்ல முறையில் ரைசோம் வளர்ச்சி நடைபெறுகிறது. பின் ரைசோம்களிலிருந்து முளை மொட்டுக்கள் வரத்துவங்குகிறது. இந்த முளை மொட்டுக்களே வளர்ச்சியடைந்து மூங்கிலாக வெளிவருகிறது. பல மூங்கில்கள் சேர்ந்து மூங்கில் திரளை ஏற்படுத்துகின்றன. (clump) (படம்-11,12,13).

11. மூங்கில் திரள் தோன்றுதல்

12. சரியாக பராமரிக்கப்படாத
மூங்கில் திரள்

13. பராமரிக்கப்பட்ட மூங்கில் திரள்

(8) ஒவ்வொரு இடங்களிலும், புதியதாகத் தோற்றுவிக்கப்படும் மூங்கிலானது சென்ற பருவ மூங்கில் அடிப்படையாகக் கொண்டும், மூங்கில் திரள்களின் வயது, மழை அளவு இவைகளைக் கொண்டும் உள்ளது. ஒவ்வொரு ஆண்டும் தோற்றுவிக்கப்படும் மூங்கிலின் எண்ணிக்கை (annual recruitment) ஆண்டுதோறும் அதிகரித்துக் கொண்டே செல்கிறது.

(9) முதலாம் ஆண்டில் தோன்றிய மூங்கிலானது, குட்டையான உயரமும், குறுகலான சுற்றளவும் கொண்டுள்ளது. பின் தோன்றும் மூங்கில்கள் ஆண்டுதோறும் உயரத்திலும், சுற்றளவிலும் பெருத்துக் காணப்படுகின்றன.

(10) மூங்கிலை தோட்டம் அமைத்த மூன்று ஆண்டுகளுக்குப் பின்னர் அறுவடை (harvesting) செய்ய துவங்கலாம். ஒவ்வொரு

ஆண்டிலும் இரண்டு முறை அறுவடை செய்யலாம். அறுவடை முடிந்த பின் தகுந்த முறையில் உரமிடுதல், மேற்கொண்டு, உற்பத்தியை அதிகரிக்க வழிசெய்யும்.

(11) மூங்கிலை ஓரங்களிலிருந்து தான் வெட்ட வேண்டும். முதல் மூன்று ஆண்டுகளில் தோன்றிய மூங்கில்களை வெட்டாமல் அப்படியே விட்டு விடுவது நல்லது.

(12) அறுவடையை ஜூலை - அக்டோபர் மாதங்களில் மேற்கொள்ளக் கூடாது.

(13) எக்காரணம் கொண்டும் மூங்கிலை முழுவதுமாக அறுவடை செய்யக் கூடாது. (complete harvest) அவ்வாறு செய்தல் மூங்கில் தோட்ட அழிவுக்கு வழிகோலும்.

அத்தியாயம் - 7

நாற்று வளர்ச்சி

7.1 நாற்று வளர்ச்சி :

மூங்கில் நாற்றானது புல்லை ஒத்துக் காணப்படுகிறது. ஒரு வித்திலை தாவரமான மூங்கில் சிறப்பான வேர் அமைப்பைக் கொண்டுள்ளது. நாற்றுக்கள் முதலில் ரைசோமைத் தோற்றுவிக்கின்றன. இந்த ரைசோமிலிருந்து, வேர்கள் அடர்த்தியாக தோன்றுகிறது. இவற்றில் இரண்டாம் நிலை வளர்ச்சி ஏற்படுவதில்லை. ரைசோமிலிருந்து ஒவ்வொரு பருவத்திலும் புதிய மூங்கில் கழிகள் தோற்றுவிக்கப்படுகிறது.

7.2 ரைசோம் வளர்ச்சி :

நாற்றுக்களின் கீழ்ப்பகுதியில் தோற்றுவிக்கப்பட்ட ரைசோமானது சிறிது தூரம் செங்குத்தாக பூமியை நோக்கி வளர்ந்த பின், கிடைமட்டமாக வளைந்து, வளர்ச்சியடைந்து, முளை மொட்டுக்களை தோற்றுவிக்கின்றன. இரண்டு வகையான ரைசோம் மொட்டுக்கள் தோன்றுகின்றன. ஒன்று செதில்களால் சூழப்பட்ட கூர்மையான மொட்டாகவும், மற்றொன்று தட்டையான மொட்டாகவும் உள்ளது. முதலில் கூர்மையான மொட்டுகள் ரைசோம்களாகவும், பின் தட்டையான மொட்டுக்கள் புதிய மூங்கில் குருத்தாகவும் மாறுகின்றன. ஒவ்வொரு ஆண்டும் புதிய மூங்கில் மொட்டுக்கள் தோன்றி, அவை மூங்கிலாக வெளிவருகின்றன. மழைக் காலங்களில் ரைசோம்கள் விரைவாக நல்ல முறையில் வளர்ச்சியடைந்து அதிக எண்ணிக்கையில் புதிய கழிகளைத் தோற்றுவிக்கிறது. ரைசோம்களின் வளர்ச்சியைப் பொறுத்து ஒருமுக வளர்ச்சி, பன்முக வளர்ச்சி என்று இருவகையான மூங்கில் திரள்கள் ஏற்படுகின்றன. *(monopodial & symbodial)*

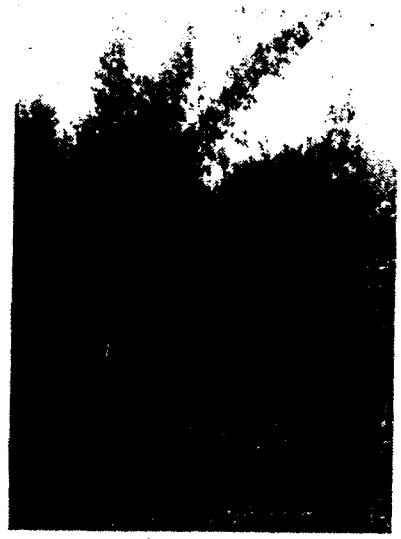
7.3 மூங்கில் வளர்ச்சியும், மாற்றங்களும் :

மூங்கிலின் வளர்ச்சி நிலையை மூன்று பகுதிகளாகப் பிரிக்கலாம். (1) மூங்கிலின் உயர வளர்ச்சி, (படம்-3), (2) கணுவைச் சுற்றியுள்ள செதில்கள் கழன்று, கிளை மொட்டுக்கள் தோன்றுதல், (படம்-14). (3) இலைகள் தோன்றுதல் (படம்-14). ரைசோம்களில் தோன்றி, மண்ணுக்கு சிறிது மேலே வரும் இள மொட்டுக்களானது, "கோமாளி" அல்லது "போத்துக்கள்" என்று அழைக்கப்படுகின்றன. (படம்-15)

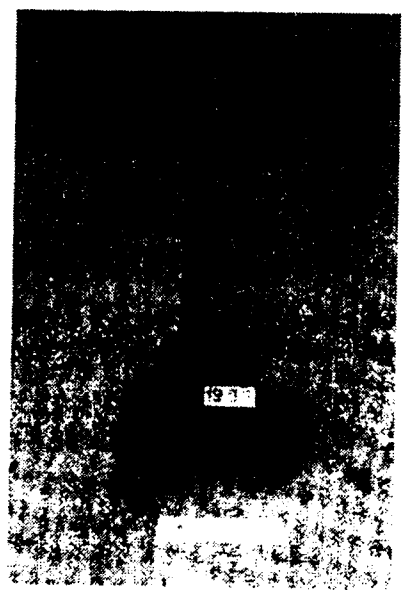
14. கணுவைச் சூழ்ந்துள்ள செதில்கள் கழன்று
கிளை மொட்டுக்கள் தோன்றுதல்

15. இளம் மூங்கில் மொட்டு

இந்த நிலையில் போத்துக்களானது, முற்றிலும் செதில்களால் சூழப்பட்டு, அவற்றில் எந்தவித கணுவிடைப் பகுதியும் இல்லாமல் சுமார் 30 - 40 செ.மீ. உயரத்துடனும் இருக்கும். சுருக்கமாகக் கூறினால் சர்க்கஸ் கோமாளியின் தொப்பி போல இருக்கும். போத்துக்கள் தோன்றிய முதல் பத்து நாட்கள் வரை வளர்ச்சி மிக மெதுவாக நடைபெறும். பின் மிக வேகமான வளர்ச்சியைப் பெறுகின்றன. அதாவது சராசரியாக நாள் ஒன்றுக்கு 30 செ.மீ. வரை வளர்கிறது. 70லிருந்து 90 நாட்களுக்குள் ஒரு மூங்கில் முழுமையான வளர்ச்சியைப் பெற்றுவிடுகிறது. முதல் முப்பது நாட்களுக்குள் உயர வளர்ச்சியை முழுமையாக அடைந்து விடுகிறது. (படம்-16) பின் கணுவைச் சுற்றியுள்ள செதில்கள் சுழன்று விழ, கிளை மொட்டுகள் தோன்றுகிறது. பின்னர் கிளைகள், அடுத்த இருபது நாட்களுக்குள் முழுமையான நீள வளர்ச்சியை அடைகின்றன. கிளைகளின் வளர்ச்சிக்குப் பின்னர் இலை மொட்டுக்கள் தோன்றுகின்றன. இதிலிருந்து இலைகள் தோன்றுகின்றன. இலைகள் தோன்றிய பின்னர் ஒரு மூங்கிலின் முழுமையான வளர்ச்சி முடிவடைந்து விடுகிறது. பிறகு அதன் கடினத் தன்மையில் மட்டும் மாறுதல்கள் நிகழ்கின்றன. (படம்-17)



16. தமிழ்நாட்டில் கள்ளிப்பட்டியில் உள்ள மூங்கில் தோட்டம்



17. 6-ம் வருட மூங்கில், ரைசோமுடன்

7.4 ஆண்டுதோறும் உற்பத்தியாகும் மூங்கில் எண்ணிக்கை :

ஒரு இடத்தின் மூங்கிலின் உற்பத்தியானது, ஒவ்வொரு மாதங்களும் தோன்றும் மூங்கிலின் எண்ணிக்கையைப் பொருத்தே உள்ளது. ஒரு இடத்தில் தோன்றுகின்ற மூங்கிலின் எண்ணிக்கையானது அந்த இடத்தின் மழையளவு, மூங்கில் திரளின் வயது போன்றவற்றை அடிப்படையாகக் கொண்டுள்ளது. இந்தியாவில் பொதுவாக மழைக்காலங்களில் அதிக எண்ணிக்கையில் மூங்கில்கள் தோன்றுகின்றன.

தமிழ்நாட்டில், கள்ளிப்பட்டி என்னும் ஊரில் 1987-ம் ஆண்டு மூங்கில் தோட்டம் அமைக்கப்பட்டது. ஒரு ஹெக்டேருக்கு 250 நாற்றுக்கள் 6 மீ X 6 மீ இடைவெளியில் நடப்பட்டது. அதற்கு அடுத்த ஆண்டு, அதாவது 1988-ல் மூங்கில் கழிகள் தோன்றின. முதலாம் ஆண்டில் 5 மூங்கில்கள் ஒரு திரளில் தோன்றியது. பின் ஒவ்வொரு ஆண்டும் தோன்றுகின்ற, மூங்கிலின் எண்ணிக்கையானது, ஒவ்வொரு ஆண்டும் அதிகரித்து 6-ம் ஆண்டு வரை அதிகரித்துக் கொண்டு உள்ளது என கண்டறியப்பட்டுள்ளது. (சண்முகவேல 1995). 7-ம் ஆண்டிலிருந்து 10-ம் ஆண்டு வரை மூங்கிலின் எண்ணிக்கை குறைவாகவே உள்ளது. (அட்டவணை-4). இதே போல் குறிப்பிட்ட ஆண்டுக்குப் பின் மூங்கிலின் எண்ணிக்கை குறைந்து வருவதை வங்கதேசத்தில் உள்ள வனவியல் ஆராய்ச்சி நிறுவன ஆய்விலும் தெரிவிக்கப்பட்டுள்ளது. (அட்டவணை-5) அனானிமஸ் (1990), மூங்கிலின் எண்ணிக்கை, நான்காம் ஆண்டுக்குப் பிறகு குறைவாக, இந்தியாவில் தனேரி என்ற இடத்தில் மேற்கொண்ட ஆய்வில் தெரிவித்துள்ளார். (அட்டவணை-6), கோன்டாஸ், (1988)ல் 10 ஆண்டுகள் வரை மூங்கிலின் எண்ணிக்கை அதிகரித்து வருவதாக கண்டறிந்துள்ளார். (அட்டவணை-7). அத்துமான் (1992)ல் மலேசியாவில் கைகாண்டோக்ளோஸ்கார்டெக்னி என்ற சிற்றினத்தில் மூன்று ஆண்டுகளுக்குப் பின் ஆண்டுதோறும் உருவாகும் மூங்கிலின் எண்ணிக்கை குறைய துவங்குவதாகத் தெரிவித்துள்ளார். (அட்டவணை-8)

7.5 மூங்கில் உயரமும், சுற்றளவும் :

மூங்கில் "போத்துக்கள்" துவங்கிய இரண்டிலிருந்து மூன்று மாதங்களுக்குள், அதனுடைய உயரம், சுற்றளவு இவற்றில் முழுமையான வளர்ச்சியைப் பெற்று விடுகின்றன. அதன் பின்னர் இவையிரண்டிலும் மாற்றங்கள் குறிப்பிடும்படி ஏற்படுவதில்லை. (மக்ளூர் 1967, பேனிக் 1980, பூதர் 1981, சண்முகவேல் 1995). முதலாம் ஆண்டில் தோன்றிய மூங்கிலானது குட்டை யாளதாகவும், குறுஞ்லான சுற்றளவும் கொண்டதாகவும் உள்ளது. பின்னர் 6 ஆண்டுகள் வரை இந்த நிலை உள்ளது. 6 ஆண்டுக்குப் பின்னர் உயரமும், சுற்றளவும் குறையத் துவங்குகிறது என்பது பெரு மூங்கிலில் கண்டறியப்பட்டுள்ளது. (*பாம்புசா லாக்சிஸ்பிகுலேடா, பா. டியூல்டா, 7 ஆண்டுகள் பா. வல்காரிஸ், பா. பால்கோவா*). இந்த ஆண்டுகளுக்குப் பிறகு, குறிப்பிட்ட சிற்றினங்களின் மூங்கில் திரள்கள் உயரமான, பருமனான மூங்கில்களை உற்பத்தி செய்வது இல்லை.

7.6 மாதந்தோறும் உற்பத்தியாகும் மூங்கிலின் எண்ணிக்கை :

ஒரு மூங்கில் தோட்டத்தில் உள்ள, மூங்கில் திரள்கள் மாதந்தோறும் எவ்வளவு எண்ணிக்கையில் மூங்கிலை உற்பத்தி செய்கின்றன என்பதைப் பற்றி ஆய்வு மேற்கொள்ளப்பட்டது. ஒரு ஹெக்டேரில் 15 மூங்கில் திரள்களை ஆங்காங்கே எடுத்துக் கொண்டு இந்த ஆய்வை சண்முகவேல், 1995-ம் ஆண்டு மேற்கொண்டார். ஒவ்வொரு மாதமும் புதியதாக தோன்றும் மூங்கிலின் எண்ணிக்கை, அவற்றின் உயிர்த்தன்மை (survival) போன்றவை கணக்கில் கொள்ளப்பட்டது. அந்த ஆய்வின் முடிவு (அட்டவணை-3)ல் தெரிவிக்கப்பட்டுள்ளது. செப்டம்பரிலிருந்து நவம்பர் வரை அதிக எண்ணிக்கையில் மூங்கில் உற்பத்தியானது என கண்டறியப்பட்டுள்ளது. இந்த ஆய்வில் 1993-ம் ஆண்டு, கள்ளிப்பட்டி மூங்கில் தோட்டத்தில், சராசரியாக 17 மூங்கில்கள் தோன்றியதாகக் கண்டறியப்பட்டுள்ளது.

7.7 ஒவ்வொரு நாளும் உயர வளர்ச்சி :

(Daily height growth)

ஒவ்வொரு நாளும், குறிப்பிட்ட இடத்தில், சீதோஷ்ண நிலையில் மூங்கிலின் உயர வளர்ச்சி என்ன என்பதை அறிய ஆய்வு மேற்கொள்ளப் பட்டது. புதியதாகத் தோன்றிய 15 மூங்கில் திரள்களை எடுத்துக் கொண்டு, அவை முழு உயர வளர்ச்சியை அடையும் வரை 2 நாட்களுக்கு ஒருமுறை உயரத்தை அளந்து பார்த்து இந்த ஆய்வு மேற்கொள்ளப்பட்டது. எடுத்துக் கொள்ளப்பட்ட 15 திரள்களில், ஒவ்வொரு திரளிலும் 5 போத்துக்கள் வீதம், மொத்தம் 75 போத்துக்களில், வண்ணம் பூசி மற்ற போத்துக்களிலிருந்து பிரித்தெடுக்கப்பட்டது. இந்த போத்துக்கள் 1.37 மீட்டர் உயர வளர்ச்சியை அடைந்ததும் அதன் சுற்றளவும் கணக்கிடப்பட்டது. பாம்பூசா பேம்போ சிற்றினத்தில், கைகாண்டோக்குளோ லெவிஸ், கைலிகுலேடா சிற்றினத்தைப் போலவே 4-5 மாதங்களில் முழுமையான உயர வளர்ச்சி முடிந்து விடுகிறது. மூங்கில் தோட்டத்தில் சராசரியாக 30 செ.மீ. வளருவதாக இந்த ஆய்வின் மூலம் கண்டறியப்பட்டது. இந்த அளவு, குறிப்பிட்ட இடத்தின் மண்ணின் தன்மை, ஈரப்பதம், கிடைக்கும் தனிமங்களின் அளவு இவற்றைப் பொருத்து மாறுபடும். (அட்டவணை-10).

அட்டவணை - 4

தமிழ்நாட்டிலுள்ள கள்ளிப்பட்டியில் பெருமூங்கில் தோட்டத்தில் தோன்றிய மூங்கில்களின் எண்ணிக்கை

	1	2	3	4	5	6	7	8	9
ஒரு மூங்கில் திரளில் தோன்றிய மூங்கில் எண்ணிக்கை	5	9	14	15	16	17	13	11	6
மொத்த மூங்கில்கள் (ஹெக்டேரில்)	1250	2250	3000	3500	4000	4250	3250	2750	1500
பருமன் (செமீ)	2.13±0.22	3.13±0.22	4.2±0.25	4.9±0.20	6.2±0.25	8.2±0.25	5.4±0.12	4.1±0.20	2.8±0.25
உயரம் (மீ)	1.40±0.37	3.26±0.20	9.6±0.76	21.6±1.49	27.3±0.52	29.0±0.56	20.5±1.00	16.0±1.25	8.5±1.15

அட்டவணை - 5

வங்கதேசத்தில் உள்ள வனவியல் ஆராய்ச்சி நிறுவனத்தில் 10 ஆண்டுகளில் தோன்றிய மூங்கில்களின் எண்ணிக்கை

மூங்கில் திரள் வயது	பாம்பூசா வல்காரிஸ்		பாம்புசா பால்கோவா		பாம்புசா லாஞ்சிஸ்பிகுலேடா		பாம்புசா டுல்டா		பாம்பூசா பக்கிபெரா	
	மூங்கில் எண்ணிக்கை	சுற்றளவு (செ.மீ.)	மூங்கில் எண்ணிக்கை	சுற்றளவு (செ.மீ.)	மூங்கில் எண்ணிக்கை	சுற்றளவு (செ.மீ.)	மூங்கில் எண்ணிக்கை	சுற்றளவு (செ.மீ.)	மூங்கில் எண்ணிக்கை	சுற்றளவு (செ.மீ.)
1	1.6	50.0	1.2	28.5	1.8	30.0	3.0	87.0	2.5	92.2
(1973)	0.2	4.5	0.2	2.0	0.4	5.2	0.5	13.2	0.5	20.5
2	2.8	105.0	2.3	66.3	2.7	66.5	3.8	153.0	5.6	145.9
(1974)	0.3	10.0	0.9	13.5	0.6	13.0	0.4	16.6	1.7	23.2
3	3.2	162.6	1.7	102.0	4.1	140.2	8.2	243.0	12.5	301.0
(1975)	0.7	22.0	0.2	14.0	0.6	16.5	1.3	28.3	2.5	42.0
4	5.3	273.4	2.8	177.0	6.2	222.0	5.7	307.0	16.4	395.4
(1976)	1.2	35.5	0.4	22.6	0.5	24.7	0.9	36.5	4.2	53.3
5	5.2	378.0	3.2	232.0	7.0	286.4	8.8	439.3	23.6	529.3
(1977)	1.7	50.3	0.8	38.0	1.3	20.6	2.3	56.3	7.2	105.6
6	3.6	456.3	2.2	250.0	6.7	372.0	4.5	464.0	25.3	624.3
(1978)	0.8	62.1	0.4	29.4	1.3	28.2	1.0	51.0	4.6	115.2
7	3.2	508.3	2.4	132.5	5.0	430.0	4.9	520.1	26.6	805.4
(1979)	0.6	64.4	0.5	32.5	1.0	35.0	1.2	42.0	8.7	146.1
8	3.2	555.0	1.8	320.5	6.6	507.6	3.7	527.2	25.1	980.6
(1980)	0.6	75.8	0.5	24.0	1.4	66.6	0.3	61.6	6.2	170.5
9	2.6	603.0	2.2	376.0	5.8	648.3	4.8	571.0	31.1	1268.0
(1981)	0.6	58.0	0.5	53.7	1.0	109.3	1.8	57.6	8.0	247.0
10	2.8	705.0	2.2	414.2	5.7	690.0	2.7	586.7	35.7	1432.3
(1982)	0.7	114.5	0.5	58.3	1.6	132.3	0.4	207.8	13.3	281.0

அட்டவணை - 6

ரைசோமை வேருடன் எடுத்து மற்ற இடங்களில் நடுவதன் மூலம் தோன்றிய மூங்கில்களின் எண்ணிக்கை

ஆண்டு	தோன்றிய புதிய மூங்கில் களின் எண்ணிக்கை	மொத்த மூங்கில் களின் எண்ணிக்கை	அகற்றப் பட்ட 1,2 வயது உடைய மூங்கில் களின் எண்ணிக்கை	மொத்தமாக அகற்றப் பட்ட மூங்கில் களின் எண்ணிக்கை	மீதம் உள்ளவை
1970	7	7	-	-	7
1971	13	20	8	8	12
1972	14	34	-	8	26
1973	24	58	20	28	30
1974	18	76	6	34	42
1975	12	88	22	56	32
1976	20	108	-	56	52

அட்டவணை - 7

பெரு மூங்கிலில் உருவான மொத்த மூங்கில்களின் எண்ணிக்கை

ஆண்டு	மொத்த மூங்கில்களின் எண்ணிக்கை	தாய்வகை மூங்கில் வகை-I	தாய்வகை மூங்கில் வகை-II	பழைய மூங்கில்களின் எண்ணிக்கை	மொத்த மூங்கில்களின் எண்ணிக்கை	வெட்டுவதற்கு ஏற்ற மூங்கில்களின் எண்ணிக்கை
1978	8	5	3	20	36	20
1979	12	8	5	3	28	-
1980	18	12	8	3+5	46	-
1981	27	18	12	3+5+8	73	16
1982	40	27	18	12	97	-
1983	60	40	27	12+18	157	-
1984	90	60	40	12+18+27	247	57
1985	135	90	60	40	325	-
1986	135	135	90	40+60	325	-
1987	300	200	135	40+60+90	825	190

அட்டவணை - 8

கைகாண்டோக்லோ ஸ்கார்டெக்னி சிற்றினத்தில் தோன்றிய மூங்கில்களின் எண்ணிக்கை (ஹெக்டேரில்)

விபரம்	மூங்கில் திரள்களின் மொத்த எண்ணிக்கை	சராசரியாக மூங்கில்களின் எண்ணிக்கை(மொ)	சராசரியாக மூங்கில்களின் எண்ணிக்கை ஒரு மூங்கில் திரளில்	மூங்கில் சுற்றளவு (செமீ)	மூங்கில்களின் சராசரி உயரம்		
					<10	10-15	>15
1.வனப்பகுதியில் உள்ள மூங்கில்கள்	422	8018	19.0	6.8	4297	3341	380
2. தோட்டவகை மூங்கில்							
ஒரு ஆண்டு மூங்கில்	400	3440	8.6	2.1	3440	-	-
இரு ஆண்டு மூங்கில்		4320	10.8	3.3	4032	288	-
மூன்று ஆண்டு மூங்கில்		2480	6.2	4.6	1488	992	-
மொத்தம்		10240	25.6		8960	1280	-
சதவீதம்					87.5	12.5	

அட்டவணை - 9

மாதந்தோறும் உற்பத்தியாகும் மூங்கில்களின் எண்ணிக்கை

(மாதிரி மூங்கில் திரளின் எண்ணிக்கை)

மாதம்	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S
ஜனவரி	3	-	4	-	4	1	1	1	2	-	3	1	4	-	4	1	3	1	3	1	4	1	3	-	4	1	1	-	1	1
பிப்ரவரி	4	1	4	-	2	-	2	-	3	1	4	1	3	1	3	1	4	1	4	1	4	-	4	1	3	-	2	1	2	1
மார்ச்	3	1	3	1	3	1	3	-	4	1	3	-	4	2	5	1	2	-	3	1	3	-	5	2	4	1	3	1	3	1
ஏப்ரல்	2	-	2	-	3	-	2	1	6	1	2	-	3	-	4	-	3	-	4	-	-	-	6	1	5	2	-	-	4	1
மே	2	-	2	-	4	1	4	1	3	-	3	-	4	-	3	-	4	1	3	-	-	-	3	-	-	-	-	-	-	-
ஜூன்	3	-	4	2	4	2	6	2	2	-	4	2	3	2	2	1	5	2	4	1	3	1	4	1	3	1	4	2	3	1
ஜூலை	5	-	5	2	6	3	8	3	6	3	6	3	4	2	4	3	8	4	6	3	4	1	6	3	7	3	5	1	6	3
ஆகஸ்ட்	4	1	5	2	7	3	6	2	8	3	9	4	6	2	6	3	9	3	9	2	5	2	8	3	5	3	6	3	4	2
செப்டம்பர்	8	4	6	3	8	2	6	4	7	4	6	3	4	1	6	3	3	1	7	3	6	3	8	4	6	4	4	3	6	4
அக்டோபர்	6	3	4	1	4	2	3	1	3	-	4	1	6	4	3	2	4	2	4	1	6	4	6	3	3	2	2	1	4	3
நவம்பர்	6	3	3	1	3	1	3	-	4	1	3	1	4	2	6	2	3	1	3	1	4	2	4	1	4	2	3	1	3	1
டிசம்பர்	5	1	4	2	3	1	2	2	3	1	3	1	3	2	5	2	2	1	6	2	3	1	3	-	3	1	4	2	4	2
மொத்தம்		16		14		17		17		15		17		18		19		17		16		15		19		20		15		20

C - புதியதாக தோன்றிய மூங்கில் எண்ணிக்கை S - தோன்றியவற்றில் வளர்ந்தவை

அட்டவணை - 10

ஓவ்வொரு நாளும் உயர வளர்ச்சி

நாட்கள்	மூங்கில் திரள் எண்														
	1			2			3			4			5		
	உயரம்	பருமன்	அடிப்பருமன்	உயரம்	பருமன்	அடிப்பருமன்	உயரம்	பருமன்	அடிப்பருமன்	உயரம்	பருமன்	அடிப்பருமன்	உயரம்	பருமன்	அடிப்பருமன்
	செமீ.														
2	12	-	4	25	-	3.5	21	-	4.5	44	-	3.5	46	-	4.5
4	20	-	-	28	-	-	34	-	-	61	-	-	65	-	-
6	33	-	-	34	-	-	45	-	-	1.01	-	-	99.5	-	-
8	52	-	-	63	-	-	64	-	-	1.49	-	-	1.4	-	-
10	69	-	-	78	-	-	93	-	-	2.09	-	-	1.5	-	-
12	76	-	-	1.05	-	-	1.17	-	-	2.27	-	-	1.7	-	-
	மீ.														
14	1.02	3.5	4.5	1.44	3.5	4.5	1.51	3.5	5.5	2.5	4.5	5	2.3	4.5	5.5
16	1.52	-	-	1.91	-	-	1.94	-	-	3.1	-	-	2.7	-	-
18	1.9	-	-	2.5	-	-	2.0	-	-	4.0	-	-	3.0	-	-
20	2.0	-	-	2.7	-	-	2.7	-	-	4.2	-	-	3.3	-	-
22	2.2	-	-	3.5	-	-	3.8	-	-	4.4	-	-	3.5	-	-
24	2.5	-	-	4.0	-	-	4.2	-	-	4.5	-	-	3.7	-	-
26	2.6	-	-	4.2	-	-	4.5	-	-	4.5	-	-	3.9	-	-
28	2.8	-	-	4.4	-	-	4.7	-	-	4.7	-	-	4.2	-	-
30	3.4	-	-	5.0	-	-	5.0	-	-	5.2	-	-	4.9	-	-
32	4.0	-	-	5.5	-	-	5.7	-	-	5.7	-	-	5.5	-	-
34	4.5	-	-	6.2	-	-	6.3	-	-	6.6	-	-	5.9	-	-
36	5.5	-	-	6.7	-	-	6.8	-	-	7.0	-	-	6.5	-	-
38	5.7	-	-	7.0	-	-	7.2	-	-	7.2	-	-	7.0	-	-
40	6.0	-	-	7.0	-	-	7.2	-	-	7.2	-	-	7.0	-	-
42	6.0	-	-	7.0	-	-	7.2	-	-	7.2	-	-	7.3	-	-
46	6.5	6.5	7	7.4	5.5	7.5	7.9	6.5	6.9	7.6	5.5	6.5	8.0	5.5	7.5
52	8.0	-	-	8.2	-	-	8.9	-	-	8.6	-	-	8.7	-	-

நாட்கள்	மூங்கில் திரள் எண்														
	1			2			3			4			5		
	உயரம்	பருமன்	அடிப்பருமன்	உயரம்	பருமன்	அடிப்பருமன்	உயரம்	பருமன்	அடிப்பருமன்	உயரம்	பருமன்	அடிப்பருமன்	உயரம்	பருமன்	அடிப்பருமன்
	மீ.														
59	12.0	-	-	12.5	-	-	12.9	-	-	12.7	-	-	13.0	-	-
61	14.5	-	-	14.7	-	-	15.0	-	-	15.5	-	-	15.5	-	-
64	16.0	-	-	16.7	-	-	17.5	-	-	17.0	-	-	17.9	-	-
66	18.5	-	-	18.0	-	-	18.5	-	-	18.0	-	-	19.5	-	-
70	19.0	-	-	20.5	-	-	19.5	-	-	20.5	-	-	21.5	-	-
72	19.9	7.5	9.5	21.5	6.5	7.5	21.5	8	8.5	22.0	6.5	8.5	22.0	6.5	7.5
75	20.5	-	-	22.0	-	-	22.0	-	-	22.5	-	-	22.5	-	-
77	21.0	-	-	22.5	-	-	22.5	-	-	22.5	-	-	23.0	-	-
79	21.4	-	-	22.7	-	-	22.8	-	-	22.7	-	-	23.3	-	-
82	22.0	-	-	23.0	-	-	23.0	-	-	23.4	-	-	24.0	-	-
84	22.3	-	-	23.4	-	-	23.5	-	-	23.5	-	-	24.3	-	-
86	23.0	-	-	24.0	-	-	24.0	-	-	24.0	-	-	24.0	-	-
88	23.5	-	-	24.0	-	-	24.3	-	-	24.0	-	-	24.0	-	-
90	23.5	-	-	24.0	-	-	24.0	-	-	24.2	-	-	24.4	-	-
92	23.5	-	-	24.0	-	-	24.0	-	-	24.7	-	-	24.5	-	-
94	24.0	-	-	24.0	-	-	24.4	-	-	24.3	-	-	24.0	-	-
96	24.5	-	-	24.5	-	-	24.7	-	-	24.7	-	-	24.5	-	-
98	27.5	-	-	27.5	-	-	27.5	-	-	27.8	-	-	28.0	-	-
100	28.0	8.5	10	28.0	8	9.5	28.0	8.5	10.5	28.0	8	10	28.0	8.5	10.5
105	28.0	-	-	28.0	-	-	28.0	-	-	28.0	-	-	28.0	-	-
107	28.0	-	-	28.5	-	-	28.0	-	-	28.0	-	-	28.5	-	-
150	28.5	-	-	28.5	-	-	28.5	-	-	28.5	-	-	28.5	-	-
180	29.5	-	-	28.5	-	-	28.0	-	-	28.5	-	-	28.5	-	-
195	29.5	-	-	28.5	-	-	28.5	-	-	28.5	-	-	28.5	-	-
210	28.5	8.5	10	28.5	8	9.5	28.5	8.5	10.5	28.5	8	10	28.5	8.5	10.5

அத்தியாயம் - 8

மூங்கில் உற்பத்தி

சூரி & சவுகான் (1984)-ல் திசு வளர்ப்பு மூலம் பெறப்பட்ட நாற்றுக்களை 5மீ X 5மீ இடைவெளியில் நடவு செய்து அமைத்த மூங்கில் தோட்டத்தில், 3-ம் வருடத்தில், நாற்றுக்கள் ஒவ்வொன்றும் மூங்கில் திரள்களை (clump) ஏற்படுத்தின. இந்த நாற்றுக்கள் 6-ம் வருடத்தில் முழுவதும் பயன் தரக்கூடிய மூங்கிலைத் தோற்றுவித்தன. சராசரியாக 5 புதிய மூங்கில்களை ஒவ்வொரு மூங்கில் திரளும் ஏற்படுத்தின. மொத்தமாக ஒரு ஹெக்டேரில் 275 - 300 மூங்கில்கள் உற்பத்தியாகின. அதில் பெரிய மூங்கில் 5 செ.மீ. சுற்றளவும், 6-8 மீட்டர் உயரமும் கொண்டதாக இருந்தன. ஒரு மூங்கில் 2 - 2½ கிலோ எடையும் கொண்டிருந்தன. நல்ல முறையில் பராமரிக்கப்படும் ஒரு மூங்கில் தோப்பில், முதல் அறுவடையில் ஹெக்டேருக்கு 3-4 டன்களும், இரண்டாவது அறுவடையில் 5-6 டன்களும், மூன்றாவது அறுவடையில் 8 டன்களும் மூங்கில்கள் இருக்கும். இதனை அடிப்படையாகக் கொண்டு, மூங்கில் வாழ்நாள் முழுவதும் கணக்கில் (சுமார் 32 ஆண்டுகள்) கொண்டு பார்க்கும் போது 70-74 டன் மூங்கில் உற்பத்தியாகலாம் என்று சூரி மற்றும் சவுகான் (1984) தங்களது ஆராய்ச்சியில் தெரியப்படுத்தியுள்ளனர்.

பின்னர், டாடா ஆய்வகத்தைச் சார்ந்த சதுர்வேதி மற்றும் பாட்டியா இருவரும் 1993-ம் ஆண்டில் தரிசு நில மேம்பாட்டு ஆராய்ச்சியின் கீழ், கார, அமில தன்மையுள்ள மண்வகைகளில் மூங்கிலை நட்டு, ஆராய்ச்சி செய்தனர். பல்வேறு வகையான மரங்களை ஒரே இடத்தில் நட்டு (mixed plantation) அதில் கிடைக்கும் பலனைக் கருத்தில் கொண்டு, எந்த மர வகைகள் கலப்பு நடவுக்கு ஏற்றது எனக் கண்டறிந்து, விவசாயிகளுக்குப் பரிந்துரை செய்யும் நோக்கோடு இந்த நிலையத்தில் மேற்குறிப்பிட்ட ஆய்வை செய்தனர். இதன் மூலம் **டென்ரோகேலமஸ்**

ஸ்டிரிக்டஸ் மூங்கிலுடன், ***அகேசியா நிலோடிகா***, மற்றும் ***கேசுரினா ஈக்குசிடிபோலியா*** மர வகைகளும் சேர்த்து 1987-ம் ஆண்டு நட்டனர். இந்த மூங்கில் 1989-ம் ஆண்டு மூங்கில் திரள்களை ஏற்படுத்தத் துவங்கின. மூங்கில் வளர்ச்சி, தோன்றியுள்ள மூங்கிலின் எண்ணிக்கை போன்றவை ***அட்டவணை-11***ல் கொடுக்கப்பட்டுள்ளது. ***அட்டவணை-12***ல், இந்த வகை மாதிரி தோட்டத்தின் உற்பத்தியும் கொடுக்கப்பட்டுள்ளன. இந்த ஆய்வின் முடிவுகள் இம்மூன்று வகை சிற்றினங்களும் கலப்பின தோட்ட அமைப்பிற்கு ஏற்றவையாகக் கொண்டு, பின்னர் விவசாயிகளுக்குப் பரிந்துரையும் செய்யப்பட்டது.

அட்டவணை - 11

தரிசு நிலத்தில் வளர்க்கப்பட்ட மூங்கில் வளர்ச்சி விபரம்

	வருடம்					S.D.
	1989	1990	1991	1992		
அகேசியா நிலோடிகா x டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்						
I	15	52	58	25	37.5	17.9
II	63	76	57	70	66.5	7.2
III	10	15	24	26	18.8	6.5
IV	9	27	32	35	25.8	10.1
V	5	15	23	26	17.3	8.1
மொத்தம்	102	185	194	182	65.8	37.1
கேசுரினா ஈக்குசிடிபோலியா x டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்						
I	86	160	100	105	112.8	28.2
II	66	87	75	131	89.8	24.9
III	49	91	110	151	100.3	36.7
IV	14	37	49	84	46.8	25.3
V	11	26	47	51	33.8	16.2
மொத்தம்	226	401	381	522	382.5	105.2

அட்டவணை - 12

தரிசு நிலத்தில் நடவு செய்யப்பட்ட மூங்கில் உற்பத்தி விவரம்

	1992			1993			1994		
	மூங்கில் எண்ணிக்கை	உயிர் எடை	உலர் எடை	மூங்கில் எண்ணிக்கை	உயிர் எடை	உலர் எடை	மூங்கில் எண்ணிக்கை	உயிர் எடை	உலர் எடை
அகேசியா நிலோடிகா x டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்									
I	67	2.31	1.80	58	2.00	1.56	25	0.86	0.67
II	139	4.80	3.73	57	1.97	1.53	70	2.63	2.05
III	25	0.86	0.67	24	0.83	0.65	26	0.90	0.70
IV	36	1.24	0.96	32	1.11	0.86	35	1.21	0.94
V	20	0.69	0.54	23	0.79	0.61	26	0.90	0.70
மொத்தம்	287	1.98	1.54	194	1.34	1.04	182	1.26	0.98
கேசுரினா ஈக்குசிடிபோலியா x டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்									
I	246	8.50	6.61	100	3.45	2.69	105	3.63	2.82
II	153	5.29	4.11	75	2.59	2.02	131	4.53	3.52
III	140	4.84	3.76	110	3.80	2.96	151	5.22	4.06
IV	51	1.76	1.37	49	1.69	1.32	84	2.90	2.90
V	37	1.28	0.99	47	1.62	1.26	51	1.76	1.37
மொத்தம்	627	4.33	3.37	381	2.63	2.05	522	3.61	2.81

உயிர் எடை, மற்றும் உலர் எடை டன் / ஹெக்டேரில் கொடுக்கப்பட்டுள்ளது.

அதற்குப் பின் சண்முகவேல் (1987)-ம் ஆண்டில் பெருமூங்கிலைக் கொண்டு தோட்டம் அமைத்து 1995-ம் ஆண்டு வரை அதன் வளர்ச்சி, **உற்பத்தி போன்றவற்றைப் பற்றி ஆராய்ச்சிகள் செய்து, 1995-ம் ஆண்டில்** தனது டாக்டர் பட்டத்திற்கான ஆய்வுக் கட்டுரைச் சமர்ப்பித்தார். அந்தக் கட்டுரையில் மூங்கில் வளர்ப்பு மற்றும் பராமரிப்பு முறைகளையும் விளக்கமாகக் கூறப்பட்டுள்ளது. 1987-ம் ஆண்டில், திசு வளர்ப்பு முறைக் கொண்டு, பெறப்பட்ட நாற்றுக்களைக் கொண்டு 6மீ X 6மீ இடை-வெளியில் நடவு செய்து, மூங்கில் தோட்டம் அமைத்து, மூங்கிலின் உற்பத்தியைப் பற்றிய ஆய்வுகள் மேற்கொள்ளப்பட்டது. நடவு செய்யப்பட்ட அனைத்து நாற்றுக்களும் ஒரு ஆண்டிற்குள் முழுமையாக ரைசோம்களை தோற்றுவித்து, அதிலிருந்து முதலாவது ஆண்டில் 5 மூங்கில் முளை மொட்டுகள் தோன்றி, மூங்கிலாக வளர்ச்சியடைந்தது. பின் 9, 14, 15, 16 மற்றும் 17 மூங்கில்கள் ஒரு மூங்கில் திரளில் முறையே 2, 3, 4, 5 மற்றும் 6-ம் ஆண்டில் உற்பத்தியாகின்றன. அதன் பின், 13, 11 மற்றும் 6 மூங்கில்கள் என 7, 8 மற்றும் 9-ம் ஆண்டுகளில் குறையத் துவங்கின. இந்த தோட்டத்தில் மிகப் பெரிய மூங்கிலானது 29 மீட்டர் உயரமும் 8.5 செ.மீ. பருமனும் கொண்டதாக இருந்தது. ஒவ்வொரு மூங்கிலும் சராசரியாக 68 கிலோ எடையளவை 6-ம் ஆண்டில் கொண்டிருந்தது. 1 முதல் 10-ம் ஆண்டு வரை உற்பத்தியான மூங்கிலின் உயரம், பருமன், உயிர் எடை போன்ற விவரங்கள் **அட்டவணை** 13-21-ல் கொடுக்கப்பட்டுள்ளது. சராசரி வருடாந்திர உயிர் எடை உற்பத்தியானது ஒவ்வொரு ஆண்டும் அதிகரித்துக் கொண்டே இருந்தது. ஆனால் நிகர முதன்மை உற்பத்தியும் (net primary production), உயிர் எடை சேர்க்கையும் (biomass accumulation) மிக அதிகமாக 5-ம் ஆண்டில்தான் நடந்துள்ளது என கண்டறியப்பட்டது. அதாவது ஆண்டிற்கு 124.08 டன்/ஹெக்டேர்/நிகர முதன்மை உற்பத்தி(அட்டவணை-22). பெரு மூங்கிலின் ஒரு ஹெக்டேரின் மொத்த உற்பத்தி விவரம் **அட்டவணை-23**ல் கொடுக்கப்பட்டுள்ளது.

மலேசியாவிலுள்ள வனவியல் ஆராய்ச்சி நிலைய விஞ்ஞானி அத்துமான் 1992-ம் ஆண்டில் **ஐய்ஜாண்டிக்ளோ ஸ்கார்டெக்னி** என்ற மூங்கில் சிற்றினத்தின் உற்பத்தியைப் பற்றிய ஆய்வுகளை மேற்கொண்டார். ஒரு ஹெக்டேரில் 422 மூங்கில் திரள்கள் கொண்ட தோப்பில், சராசரியாக 19 மூங்கில்கள் ஒரு மூங்கில் திரளில் தோன்றியுள்ளது என்பதைக் கண்டறிந்தார். மேலும் இயற்கையாக காட்டில் உள்ள மூங்கிலின் உற்பத்தி (71.9 டன்/ஹெ$^{-1}$)யை விட மூங்கில் தோப்பில் குறைவான (36.2 டன்/ஹெ$^{-1}$) உற்பத்தியாகியுள்ளதையும் தெரிவித்தார். **ஜ. ஸ்கார்டெக்னி**யின் உற்பத்தி நிலவரம் **அட்டவணை-24**-ல் கொடுக்கப்பட்டுள்ளது.

தரைமட்டத்திற்கு மேலேயுள்ள உயிர் எடை பங்கீடு (above ground biomass percentage contribution) சதவீதம் (அட்டவணை-25) மூங்கில் தோப்பின் வயதைப் பொருத்தே காணப்படுகிறது. இலைகளின் சதவீதப் பங்கீடு வயது அதிகமாகும் போது 7 சதவீதத்திலிருந்து (1 ஆண்டு) 1 சதவீதமாகக் (6-ம் ஆண்டு) குறைகிறது. இந்த நிலை மூங்கிலின் வயது அதிகரிக்கும் போது தோன்றுகின்ற இலைகளின் எண்ணிக்கை குறைந்து வருவதைக் காட்டுகிறது. கிளையைப் பொருத்தவரை உயிர் எடை சதவீதப் பங்கீட்டில் பொதுவான நிலைமை காணப்படவில்லை. ரைசோம்களின் சதவீதப் பங்கீடானது இலைகளின் பங்கீட்டை ஒத்துக் காணப்படுகிறது. மூங்கில் தோட்டங்களில் காணப்படும் இந்த சதவீதப் பங்கீடானது, இதர மர வகைகளின் சதவீதப் பங்கீட்டை ஒத்துக் காணப்படுகிறது. **(யூகலிப்டஸ், டெரிகார்னிஸ்)**, (சிங், சர்மா, 1976) **யூ. ஹைபிரிட்** (ஜார்ஜ் 1977), **யூ. குளோபுளஸ்** (நீகி 1984, டான்டன் 1988, பாண்டே, 1989 மற்றும் ஜார்ஜ் வர்கீஸ் 1990).

அட்டவணை - 13

முதல் ஆண்டு பெரு மூங்கிலில் உயிர் எடை பங்கீடு விவரம்

வரிசை எண்	ஆய்வு மூங்கில் எண்	மூங்கில் வயது (ஆண்டுகளில்)	அடிப்பருமன் (செமீ.)	பருமன் (செமீ.)	உயரம் (மீ.)	உயிர் எடை கி.கி./மூங்கில்			நில மட்டத் திற்குமேல் மொத்த உயிர்எடை (கி.கி.)	ரைசோம்	மொத்த உயிர் எடை (கி.கி.)
						இலைகள்	கிளைகள்	மூங்கில் தண்டு			
1	1	1	2.2	2.0	1.4	0.100	0.325	0.550	0.975	0.800	1.775
2	2	1	3.5	2.0	1.0	0.125	0.400	0.450	0.975	-	-
3	3	1	3.0	2.0	1.4	0.18	0.350	0.600	1.130	-	-
4	4	1	2.5	2.0	1.8	0.100	0.400	0.750	1.250	-	-
5	5	1	2.5	2.0	1.4	0.150	0.425	0.400	0.975	-	-
6	6	1	3.2	2.0	1.4	0.110	0.300	0.450	0.860	-	-
7	7	1	3.3	2.0	1.4	0.125	0.410	0.600	1.135	-	-
8	8	1	3.5	2.0	1.4	0.190	0.425	0.625	1.240	-	-
9	9	1	3.5	2.0	1.4	0.100	0.350	0.650	1.100	-	-
10	10	1	3.2	2.0	1.4	0.115	0.425	0.500	1.040	0.750	1.790
11	11	1	3.4	2.0	1.4	0.100	0.410	0.700	1.210	-	-
12	12	1	3.0	2.0	1.8	0.150	0.450	0.900	1.500	-	-
13	13	1	3.2	2.0	1.8	0.185	0.400	0.400	0.985	-	-
14	14	1	3.5	2.0	1.8	0.125	0.400	0.800	1.325	-	-
15	15	1	3.5	2.0	1.8	0.150	0.450	0.650	1.250	0.700	1.950

அட்டவணை - 14

இரண்டாம் ஆண்டு பெரு மூங்கிலில் உயிர் எடை பங்கீடு விவரம்

வரிசை எண்	ஆய்வு மூங்கில் எண்	மூங்கில் வயது (ஆண்டுகளில்)	அடிப்பருமன் (செ.மீ.)	பருமன் (செ.மீ.)	உயரம் (மீ.)	உயிர் எடை கி.கி./மூங்கில்			நில மட்டத்திற்குமேல் மொத்த உயிர்எடை (கி.கி.)	ரைசோம்	மொத்த உயிர் எடை (கி.கி.)
						இலைகள்	கிளைகள்	மூங்கில் தண்டு			
16	16	2	3.9	3.0	3.2	0.250	0.750	2.900	3.900	1.100	5.000
17	17	2	3.9	3.0	3.5	0.225	0.700	3.100	4.025	-	-
18	18	2	4.0	3.0	3.0	0.300	0.800	2.700	3.800	-	-
19	19	2	4.2	3.0	3.0	0.325	0.950	2.500	3.775	-	-
20	20	2	4.0	3.0	3.4	0.300	0.750	2.900	3.950	-	-
21	21	2	3.8	3.0	3.5	0.300	0.900	3.000	4.200	-	-
22	22	2	3.9	3.0	3.5	0.315	0.850	2.800	3.965	-	-
23	23	2	4.0	3.0	3.0	0.200	0.900	2.400	3.500	-	-
24	24	2	4.0	3.0	3.1	0.225	0.950	2.600	3.775	-	-
25	25	2	4.5	3.0	3.4	0.300	0.750	3.000	4.050	1.700	5.750
26	26	2	3.9	3.0	3.0	0.325	0.800	2.800	3.925	-	-
27	27	2	4.0	3.5	3.4	0.390	0.950	3.700	5.040	-	-
28	29	2	4.5	3.5	3.3	0.375	0.900	3.900	5.175	-	-
29	29	2	4.0	3.5	3.2	0.325	0.800	3.500	4.725	-	-
30	30	2	4.5	3.5	3.5	0.310	0.900	3.500	4.170	1.940	6.110

அட்டவணை - 15

மூன்றாம் ஆண்டு பெரு மூங்கிலில் உயிர் எடை பங்கீடு விவரம்

வரிசை எண்	ஆய்வு மூங்கில் எண்	மூங்கில் வயது (ஆண்டுகளில்)	அடிப்பருமன் (செமீ)	பருமன் (செமீ)	உயரம் (மீ)	உயிர் எடை கி.கி/மூங்கில்			நில மட்டத்திற்குமேல் மொத்த உயிர்எடை (கி.கி.)	ரைசோம்	மொத்த உயிர் எடை (கி.கி.)
						இலைகள்	கிளைகள்	மூங்கில் தண்டு			
31	1	3	4.9	4.0	9.0	0.400	4.100	8.700	13.200	1.500	14.700
32	2	3	4.5	4.0	9.0	0.390	4.500	10.100	14.990	-	-
33	3	3	4.8	4.0	9.0	0.375	5.500	8.500	14.375	-	-
34	4	3	4.5	4.0	9.0	0.350	6.000	8.900	15.250	-	-
35	5	3	5.0	4.0	9.0	0.400	4.800	9.900	15.100	-	-
36	6	3	5.0	4.0	9.0	0.350	6.000	10.000	16.350	-	-
37	7	3	4.9	4.0	9.0	0.300	7.000	9.900	17.200	-	-
38	8	3	4.5	4.0	9.0	0.390	5.100	10.000	15.490	-	-
39	9	3	4.9	4.0	9.0	0.400	6.100	9.750	16.250	-	-
40	10	3	5.0	4.5	10.5	0.500	5.700	10.800	17.000	1.900	18.900
41	11	3	5.2	4.5	10.5	0.375	6.000	10.500	16.875	-	-
42	12	3	5.5	4.5	10.5	0.380	6.000	10.100	16.480	-	-
43	13	3	5.5	4.5	10.5	0.310	5.500	9.100	14.910	-	-
44	14	3	5.5	4.5	10.5	0.310	6.200	10.200	16.710	-	-
45	15	3	5.5	4.5	10.5	0.390	7.100	9.800	17.290	1.600	18.890

அட்டவணை - 16

நான்காம் ஆண்டு பெரு மூங்கிலில் உயிர் எடை பங்கீடு விவரம்

வரிசை எண்	ஆய்வு மூங்கில் எண்	மூங்கில் வயது (ஆண்டுகளில்)	அடிப்பருமன் (செ.மீ.)	பருமன் (செ.மீ.)	உயரம் (மீ.)	உயிர் எடை கி.கி./மூங்கில்			நில மட்டத் திற்குமேல் மொத்த உயிர்எடை (கி.கி.)	ரைசோம்	மொத்த உயிர் எடை (கி.கி.)
						இலைகள்	கிளைகள்	மூங்கில் தண்டு			
46	1	4	5.8	4.5	20	0.400	8.200	20.000	28.600	2.000	30.900
47	2	4	5.9	4.5	20	0.550	7.800	24.950	33.300	-	-
48	3	4	5.8	4.5	20	0.600	7.500	25.600	33.700	-	-
49	4	4	6.0	5.0	23	0.450	7.100	29.000	36.550	-	-
50	5	4	6.0	5.0	20	0.500	7.500	22.000	30.000	-	-
51	6	4	5.9	5.0	22	0.490	8.400	27.000	35.890	-	-
52	7	4	6.0	5.0	23	0.500	7.400	29.000	36.900	-	-
53	8	4	6.3	5.0	23	0.590	7.800	28.800	37.190	1.400	38.590
54	9	4	6.0	5.0	22	0.600	8.500	27.100	36.200	-	-
55	10	4	6.5	5.0	20	0.600	7.500	25.100	34.200	-	-
56	11	4	6.5	5.0	20	0.550	7.500	25.600	33.550	-	-
57	12	4	6.0	5.0	22	0.500	8.100	26.900	28.500	-	-
58	13	4	6.5	5.0	24	0.510	7.500	29.200	37.210	-	-
59	14	4	6.5	5.0	23	0.600	7.100	28.100	35.800	-	-
60	15	4	6.0	5.0	23	0.550	8.500	29.200	38.250	1.700	39.950

அட்டவணை - 17

ஐந்தாம் ஆண்டு பெரு மூங்கிலில் உயிர் எடை பங்கீடு விவரம்

வரிசை எண்	ஆய்வு மூங்கில் எண்	மூங்கில் வயது (ஆண்டுகளில்)	அடிப்பருமன் (செ.மீ.)	பருமன் (செ.மீ.)	உயரம் (மீ.)	உயிர் எடை கி.கி./மூங்கில்			நில மட்டத் திற்குமேல் மொத்த உயிர்எடை (கி.கி.)	ரைசோம்	மொத்த உயிர் எடை (கி.கி.)
						இலைகள்	கிளைகள்	மூங்கில் தண்டு			
61	1	5	7.5	6.0	27	0.750	8.200	39.100	48.050	2.200	50.850
62	2	5	8.0	6.0	26	0.950	7.900	46.000	54.850	-	-
63	3	5	8.0	6.0	27	0.850	8.100	45.100	54.050	-	-
64	4	5	8.0	6.0	27	0.800	8.100	49.700	58.600	-	-
65	5	5	8.0	6.0	27	0.900	8.500	48.100	57.500	-	-
66	6	5	7.5	6.0	27	0.850	8.200	46.900	55.950	-	-
67	7	5	8.0	6.0	27	0.950	8.700	51.100	60.750	-	-
68	8	5	8.0	6.5	28.5	0.900	9.000	42.200	52.100	-	-
69	9	5	8.5	6.5	27.5	0.900	9.100	42.100	52.000	2.750	54.750
70	10	5	8.5	6.5	27.5	0.950	8.900	42.100	51.850	-	-
71	11	5	8.5	6.5	27.5	0.900	8.900	48.100	57.900	-	-
72	12	5	8.5	6.5	27.5	0.900	8.500	47.000	56.400	-	-
73	13	5	8.5	6.5	27.5	0.950	8.100	51.00	60.050	-	-
74	14	5	8.5	6.5	27.5	0.850	9.000	51.000	60.850	-	-
75	15	5	8.5	6.5	27.5	0.900	8.100	52.700	61.700	2.700	64.400

அட்டவணை - 18

ஆறாம் ஆண்டு பெரு மூங்கிலில் உயிர் எடை பங்கீடு விவரம்

வரிசை எண்	ஆய்வு மூங்கில் எண்	மூங்கில் வயது (ஆண்டுகளில்)	அடிப்பருமன் (செ.மீ)	பருமன் (செ.மீ)	உயரம் (மீ)	உயிர் எடை கி.கி/மூங்கில்			நில மட்டத்திற்குமேல் மொத்த உயிர்எடை (கி.கி.)	சரசொம	மொத்த உயிர் எடை (கி.கி.)
						இலைகள்	கிளைகள்	மூங்கில் தண்டு			
76	1	6	9.5	8.0	28.0	0.950	10.100	52.100	63.150	2.600	65.150
77	2	6	10.0	8.0	28.5	0.900	8.700	53.800	62.850	.	.
78	3	6	10.0	8.0	28.5	0.900	9.100	62.200	72.100	.	.
79	4	6	10.0	8.0	28.5	0.950	9.200	57.100	67.250	.	.
80	5	6	10.0	8.0	28.5	1.000	9.500	62.100	72.700	.	.
81	6	6	10.0	8.0	28.5	0.900	8.500	56.000	65.400	.	.
82	7	6	10.0	8.0	28.5	0.950	9.700	54.000	64.650	.	.
83	8	6	9.5	8.5	29.5	1.000	9.100	56.200	66.300	.	.
84	9	6	10.5	8.5	29.5	1.000	9.100	54.100	64.200	.	.
85	10	6	10.5	8.5	29.5	1.000	9.800	61.900	72.700	2.400	75.100
86	11	6	10.5	8.5	29.5	0.850	9.500	57.100	67.450	.	.
87	12	6	10.5	8.5	29.5	0.890	9.700	56.100	66.690	.	
88	13	6	10.5	8.5	29.5	0.900	9.500	53.000	63.400	.	.
89	14	6	10.5	8.5	29.5	0.900	9.800	59.100	69.800	.	.
90	15	6	10.5	8.5	29.5	0.900	9.500	61.900	72.300	2.800	75.100

அட்டவணை - 19

ஏழாம் ஆண்டு பெரு மூங்கிலில் உயிர் எடை பங்கீடு விவரம்

வரிசை எண்	மூங்கில் வயது (ஆண்டுகளில்)	அடிப்பருமன் (செ.மீ.)	பருமன் (செ.மீ.)	உயரம் (மீ.)	உயிர் எடை கி.கி./மூங்கில்			நில மட்டத் திற்குமேல் மொத்த உயிர்எடை (கி.கி.)	ரைசோம்	மொத்த உயிர் எடை (கி.கி.)
					இலைகள்	கிளைகள்	மூங்கில் தண்டு			
1	7	6.0	5.5	20.5	0.600	6.400	35.200	42.200	2.400	44.600
2	7	5.9	5.0	20.4	0.550	6.900	36.100	43.350	-	-
3	7	6.5	5.5	20.0	0.59	1.500	36.500	43.590	-	-
4	7	5.0	5.5	20.5	0.650	7.000	37.1000	44.750	-	-
5	7	6.0	5.4	20.5	0.550	6.600	38.100	45.250	-	-
6	7	5.5	5.4	20.4	0.490	7.100	35.100	42.690	-	-
7	7	6.5	5.5	20.5	0.500	5.900	35.700	42.100	-	-
8	7	6.0	5.4	20.5	0.650	7.200	36.000	43.850	2.600	46.450
9	7	6.5	5.5	20.3	0.600	6.100	36.200	42.900	-	-
10	7	6.0	5.5	20.3	0.600	6.100	36.200	42.900	-	-
11	7	6.5	5.4	20.5	0.550	5.900	34.900	41.350	-	-
12	7	6.0	5.5	20.5	0.600	5.900	36.100	42.600	-	-
13	7	6.0	5.4	20.5	0.650	6.100	35.000	41.750	-	-
14	7	6.5	5.5	20.0	0.600	6.800	36.700	44.100	-	-
15	7	6.0	5.5	20.0	0.650	6.500	36.00	43.150	2.600	45.750

அட்டவணை - 20

எட்டாம் ஆண்டு பெரு மூங்கிலில் உயிர் எடை பங்கீடு விவரம்

வரிசை எண்	மூங்கில் வயது (ஆண்டுகளில்)	அடிப்பருமன் (செ.மீ.)	பருமன் (செ.மீ.)	உயரம் (மீ.)	உயிர் எடை கி.கி./மூங்கில்			நில மட்டத்திற்குமேல் மொத்த உயிர்எடை (கி.கி.)	ரைசோம்	மொத்த உயிர் எடை (கி.கி.)
					இலைகள்	கிளைகள்	மூங்கில் தண்டு			
1	8	5.0	4.0	16.5	0.450	5.100	28.500	34.050	2.000	36.050
2	8	5.0	4.0	16.8	0.400	5.500	23.500	29.400	-	-
3	8	5.5	4.3	17.0	0.500	6.600	23.100	30.200	-	-
4	8	5.0	4.5	16.0	0.450	5.500	26.500	32.450	-	-
5	8	5.3	4.0	16.5	0.500	5.800	20.100	26.400	-	-
6	8	5.0	4.0	16.5	0.490	5.500	25.800	31.790	-	-
7	8	5.0	4.0	16.0	0.500	5.000	26.100	32.600	-	-
8	8	5.4	4.5	16.5	0.590	5.500	27.200	33.290	-	-
9	8	5.0	4.1	16.0	0.550	5.700	26.500	32.750	2.100	34.850
10	8	5.0	4.0	16.5	0.500	5.000	24.700	31.200	-	-
11	8	5.0	4.2	16.4	0.550	5.500	23.500	29.550	-	-
12	8	5.3	4.5	16.0	0.500	5.000	18.800	24.300	-	-
13	8	5.0	4.0	16.5	0.510	6.100	27.200	33.810	-	-
14	8	5.0	4.0	16.5	0.550	5.600	25.800	31.950	-	-
15	8	5.3	4.5	16.0	0.550	6.000	28.100	34.650	1.800	36.450

அட்டவணை - 21

ஒன்பதாம் ஆண்டு பெரு மூங்கிலில் உயிர் எடை பங்கீடு விவரம்

வரிசை எண்	மூங்கில் வயது (ஆண்டுகளில்)	அடிப்பருமன் (செ.மீ.)	பருமன் (செ.மீ.)	உயரம் (மீ.)	உயிர் எடை கி.கி/மூங்கில்			நில மட்டத் திற்குமேல் மொத்த உயிர்எடை (கி.கி.)	ரைசோம்	மொத்த உயிர் எடை (கி.கி.)
					இலைகள்	கிளைகள்	மூங்கில் தண்டு			
1	9	3.5	2.8	9.5	0.300	4.000	10.100	14.400	1.660	16.000
2	9	3.5	2.8	9.0	0.300	4.150	13.500	17.950	-	-
3	9	3.5	3.0	8.5	0.350	5.000	15.100	20.450	-	-
4	9	4.0	3.0	8.5	0.400	4.000	14.200	18.600	-	-
5	9	4.0	3.0	8.5	0.300	4.100	13.000	17.400	-	-
6	9	3.5	2.8	8.0	0.325	4.300	10.000	14.625	-	-
7	9	3.5	2.8	8.5	0.300	4.700	10.500	15.500	-	-
8	9	4.0	3.0	8.5	0.290	4.100	14.100	18.490	-	-
9	9	4.0	3.0	9.0	0.300	4.000	13.500	17.800	1.300	19.100
10	9	3.5	2.8	9.0	0.350	4.200	15.100	19.650	-	-
11	9	3.5	2.8	8.5	0.300	5.000	15.500	20.800	-	-
12	9	4.0	3.0	8.0	0.300	4.500	16.100	20.900	-	-
13	9	3.5	2.8	8.5	0.310	4.500	15.100	19.910	-	-
14	9	3.5	2.8	8.5	0.350	4.000	15.000	19.350		
15	9	3.5	2.8	8.5	0.300	4.200	14.100	18.600	1.200	19.800

அட்டவணை - 22

நிகர முதன்மை உற்பத்தி மற்றும் உயிர் எடை சேர்க்கை

மூங்கில் வயது (ஆண்டுகளில்)	1	2	3	4	5	6
சராசரி வருடாந்திர உற்பத்தி	2.29	6.25	17.48	31.95	48.86	49.64
இரு ஆண்டுகளுக்கு இடையில் உற்பத்தி அதிகரிப்பு	2.29	6.25	17.48	31.95	48.86	49.64
இலை, கிளை வீழ்ச்சி	N.D.	N.D.	N.D.	15.40	17.60	20.30
நிகர முதன்மை உற்பத்தி	N.D.	N.D.	N.D.	90.76	124.08	83.85

N.D. - கணக்கிடப்படவில்லை

அட்டவணை - 23

பெரு மூங்கிலில் உற்பத்தி விவரம் (ஹெக்டேரில்)

மூங்கில் வயது (ஆண்டுகளில்)	பருமன் (செமீ)	உயரம் (மீ)	அடிப் பருமன் (செமீ)	மூங்கில் எண்ணிக்கை	ஒரு மூங்கிலில் காணப்படும் கணுக்களின் எண்ணிக்கை	உயிர் எடை (டன்னில்)			நில மட்டத்திற்கு மேல் மொத்த உயிர்எடை	ரைசோம்	மொத்த உயிர் எடை
						இலைகள்	கிளைகள்	மூங்கில் தண்டு			
1	2.3	1.4	3.1	1250	7	0.166	0.493	0.698	1.356	0.938	2.294
2	3.3	3.2	4.0	2250	16	0.668	1.897	6.795	9.360	3.150	12.510
3	4.3	9.6	5.0	3000	37	1.122	17.115	29.250	47.487	4.980	52.467
4	4.8	21.8	6.1	3500	86	1.862	27.160	92.750	121.772	6.055	127.827
5	6.3	27.2	8.3	4000	98	3.544	33.940	187.224	224.708	9.600	234.308
6	8.3	28.5	10.1	4250	103	4.021	39.886	242.730	286.637	11.220	297.857

அட்டவணை - 24

ஐய்ஜாண்டிக்ளோ ஸ்கார்டெக்னி மூங்கில் உற்பத்தி விவரம்

விவரம்	வனப் பகுதி மூங்கில் கள்	தோட்டவகை மூங்கில் வயது (ஆண்டுகளில்)			மொத்தம்
		1	2	3	
மூங்கிலின் எண்ணிக்கை (ஹெக்டேரில்)	8018	2480	4230	3440	10240 (T)
சராசரி பருமன் (செ.மீ.)	6.8	2.1	3.3	4.6	3.3 (A)
சராசரி உயரம் (மீ)	13.3	3.8	6.7	9.2	6.6 (A)
மூங்கிலின் உயிர் எடை (டன்/ஹெ)	82.15	3.3	14.1	24.4	14.8 (T)
கிளைகளின் உயிர் எடை (டன்/ஹெ)	20.00	1.0	3.9	6.5	11.4 (T)
இலைகளின் உயிர் எடை (டன்/ஹெ)	16.90	0.7	3.1	7.4	11.2 (T)
மூங்கிலின் உலர் எடை (டன்/ஹெ)	52.90	1.8	8.1	14.9	24.8 (T)
கிளைகளின் உலர் எடை (டன்/ஹெ)	9.80	0.6	2.1	3.4	6.1 (T)
இலைகளின் உலர் எடை (டன்/ஹெ)	9.20	0.3	1.5	3.5	5.3 (T)
மொத்த உலர் எடை (டன்/ஹெ)	71.90	2.7	11.7	21.8	36.2 (T)
	0.54				0.55 (T)

T - மொத்தம் ; A - சராசரி

அட்டவணை - 25

உயிர் எடை பங்கீடு சதவீதம்

மூங்கில் வயது (ஆண்டுகளில்)	பருமன் (செ.மீ.)	உயரம் (மீ.)	உயிர் எடை பங்கீடு சதவீதம் (%)			
			இலைகள்	கிளைகள்	மூங்கில் தண்டு	ரைசோம்
1	2.3	1.4	07	21	32	40
2	3.3	3.2	05	15	55	25
3	4.3	9.6	02	33	56	09
4	4.8	21.8	02	20	73	05
5	6.3	27.2	02	14	80	04
6	8.3	28.5	01	14	85	04

8.1 மொத்த உயிர் எடை : *(Total biomass)*

நான்கு வயதுடைய ***பாம்பூசா வல்காரிஸ்*** என்ற சிற்றினத்தில் மொத்த உயிர் எடை 7 டன் /ஹெ$^{-1}$, ***ஐய்ஜாண்டிக்ளோவா ஆஸ்பேரா*** சிற்றினத்தில் 1 டன்/ஹெ$^{-1}$ உள்ளது என்று கைண்ட் (1965)-ம் ஆண்டு தெரிவித்துள்ளார். ***ஜ.ஸ்கார்டெக்னி*** சிற்றினம் இயற்கையாக காட்டில், 3 ஆண்டில் 71.9 டன்/ஹெ$^{-1}$ எடையும், இந்த சிற்றினமே தோட்டத்தில் 36.36 டன்/ஹெ$^{-1}$ எடையும் கொண்டுள்ளது என மலேசியாவில் இருந்து அத்துமான் (1992) தனது ஆய்வு முடிவில் தெரிவித்துள்ளார். இந்த எடையளவு அனைத்தும், தமிழ்நாட்டில், கள்ளிப்பட்டியில் உள்ள மூங்கில் தோப்பில் 3 ஆண்டுகளில் உற்பத்தியளவு, உயிர் எடை அளவைக் காட்டிலும் மிகக் குறைவாகவே உள்ளது. கள்ளிப்பட்டியில் 3-வது ஆண்டில் 47.48 டன்/ஹெ$^{-1}$ மூங்கில் உற்பத்தி உள்ளதாக சண்முகவேல் 1995-ம் ஆண்டில் தனது ஆய்வில் தெரிவித்துள்ளார். மூங்கிலின் உயிர் எடை உற்பத்தியானது, அந்த இடத்தின் மண்ணின் தன்மை, வெப்ப நிலை, மழையளவு இவற்றைப் பொருத்து வேறுபட்டுக் காணப்படுகிறது. இதர வேகமாக வளரும் மரங்களின் எடையளவுடன் மூங்கில் எடையை ஒப்பிட்டுப் பார்க்கும் 7லிருந்து 30 சதவீதம் அதிகமாகவே உள்ளதாகத் தெரிய வருகிறது. ***யூகலிப்டஸ் குளோபுளஸ்*** (8.6 டன்/ஹெ$^{-1}$/4வது ஆண்டு, குரோமர், 1976), ***லுயூசிஜா லியூகோ செபலா*** (47 டன்/ஹெ$^{-1}$/5-வது ஆண்டு, பாணடே, 1989), ***பைனஸ் கரீபியா*** (87 டன்/ஹெ$^{-1}$ மட்விக் 1977).

8.2 தோட்ட வகை மூங்கில் இலைகளின் உயிர்வேதி பொருள்களின் தன்மையும், உற்பத்தியும் :

தாவரங்களிலுள்ள பச்சயத்தின் (chlorophyll) செயலியலைக் கொண்டுதான், உற்பத்தி நடைபெறுகிறது என்ற கருத்தை சூர்ய நாராயணன் 1978, ஹெக்டே & பவக்கார் 1983, தியாகி & தாலிக் 1988, மற்றும் மாலிக் 1993 போன்ற தாவர செயலியல் வல்லுநர்கள் வெளியிட்டுள்ளனர். மூங்கிலின் உயிர் எடை உற்பத்தியானது பச்சயத்தின்

செயல்பாட்டை ஒத்துக் காணப்படுகிறது. மூங்கில் இலைகளின் உள்ளமைப்பு (anatomy) புல் வகைகளின் உள்ளமைப்பை, ஒத்துக் காணப்படுவதோடு, பச்சயங்கள், கார்போஹைட்ரேட், ஸ்டார்ச் போன்ற வேதிப் பொருள்கள் வயதுக்கு நேர் எதிர் மறையாகக் காணப்படுகிறது. (அட்டவணை-26), (சண்முகவேல், 1995). அட்டவணையில் காணப்படும் ஆய்வு முடிவுகள் உயிர் எடை உற்பத்திக்கும், பச்சயத்திற்கும் உள்ள தொடர்பை தெளிவாகக் காட்டுவதுடன், இந்த முடிவுகள் அனைத்தும் பயிர் செய்யப்பட்ட மாங்காய் இலைகளின் வேதிப் பொருட்களை ஒத்துக் காணப்படுகிறது (மாலிக் - 1993). மூங்கிலில் தரைமட்டத்திற்கு மேல் உள்ள உயிர் எடையின் அளவு 6.9 தடவைகள் 1 ஆண்டிலிருந்து 2-ம் ஆண்டில் அதிகரித்துள்ளது. பின்வரும் 5 ஆண்டுகளில் 5.0, 2.5, 1.8, 1.2 தடவைகள் அதிகரித்துள்ளது. உயிர் எடையின் உற்பத்தி விகிதமானது ஆண்டிற்கு ஆண்டு குறைந்து வருவது தெளிவாகத் தெரிகிறது. மூங்கிலின் வயது அதிகமாக, அதிகமாக அதன் இலைகளில் காணப்படும் வேதிப் பொருட்களின் அளவு குறைந்து வருவதே காரணமாகக் கொள்ளலாம். காட்டு மூங்கில் இலைகளில் காணப்படும் வேதிப்பொருட்களின் அளவானது, தோட்டவகை மூங்கில் இலைகளின் வேதிப் பொருட்களின் அளவுடன் ஒப்பிட்டுப் பார்க்கும்போது 34 சதவீதம் அதிகரித்துக் காணப்படுகிறது. இது காட்டுவகை மூங்கில்களில் காணப்படுகின்ற மெதுவான வளர்சிதை மாற்றத்தை காட்டுவதுடன், அதனாலேயே உயிர் எடையின் அளவும் குறைவாக காட்டு வகை மூங்கிலில் இருப்பதாகத் தெரிய வருகிறது. (சண்முகவேல் 1995, கைன்ட் 1965, அத்துமான் 1992).

அட்டவணை - 26

மூங்கில் இலைகளின் உயிர்வேதிப்பொருட்களின் தன்மைகள்

வயது (ஆண்டுகளில்)	மொத்த பச்சயம் (µ/கி)	பச்சயம்-a (µ/கி)	பச்சயம்-b (µ/கி)	பச்சயம் a,b சமவீதம்	கரோட்டினாய்ட்ஸ் (µ/கி)	புரோட்டீன் (µ/கி)	கார்போஹைட்ரேட் (மி.கி./கி)	ஸ்டார்ச்ச (மி.கி./கி)
வனப்பகுதி மூங்கில்கள் தோட்ட வகை	602	266	328	0.81	91.35	10.41	12.00	811.95
1	551	248	298	0.83	64.00	7.53	8.78	588.35
2	544	237	302	0.78	58.53	7.23	7.95	537.30
3	500	230	265	0.86	53.55	6.89	7.20	495.65
4	449	212	233	0.90	50.42	6.19	7.04	481.72
5	398	194	200	0.97	49.88	6.07	6.91	475.09
6	366	174	188	0.92	48.80	5.95	6.47	469.82

8.3 பொருளாதாரக் கண்ணோட்டம் :

மூங்கில் அன்றாட வாழ்க்கையில் அனைத்து நிலைகளிலும் பயன்படுகிறது. புள்ளி விவரக் கணக்குப்படி இவை இந்திய காட்டில் 10,300 கி.மீ² பரப்பளவில் பரவிக் காணப்படுகிறது. இவற்றிலிருந்து ஆண்டுக்கு 4.5 மில்லியன் டன் உற்பத்தியாவதாகக் கணக்கிடப்பட்டுள்ளது. (கவுர் - 1987). தற்போது மூங்கிலைப் பற்றியும் பல்வேறு ஆராய்ச்சிகள் நடைபெற்று வந்தாலும் அவை இன்னும் முழுமை பெறாத நிலையிலேயே உள்ளது. உற்பத்தி மற்றும் வணிகம் இவற்றைப் பற்றிய ஆராய்ச்சிகள், மேலும் கிராமப்புற மக்களின் (மூங்கிலை அடிப்படையாகக் கொண்டு தயாரிக்கப்படும் பொருள்களின் மூலம்) பொருளாதார மேம்பாட்டுக்கு வழிகோலுவதாக அமைய வேண்டிய அவசியம் உள்ளது.

நாட்டில் மூங்கிலின் உற்பத்தியானது சீதோஷ்ண நிலைக்குத் தகுந்தவாறு மாறுபட்டுக் காணப்படுகிறது. மூங்கிலின் மூலம் கிடைக்கும் நிதி நிலைமையானது, காலநிலை, வளர்ச்சி முறைகள் மேலும் வணிக வசதி இவற்றை பொறுத்துக் காணப்படுகிறது. எனவே பல்வேறு சிற்றினங்களை வியாபார ரீதியிலும் வளர்க்கவும், வளர்ப்பதில் ஏற்படும் பிரச்சனைகள், செலவுகள், அதன் மூலம் பெறப்படும் வருவாய் போன்ற விவரங்களை புள்ளி விவரக் கணக்கில் ஆராய்ந்து நோக்குவது இன்றியமையாததாகும்.

8.3.1. பாம்பூசா பாம்போஸ் : (பெரு மூங்கில்)

இவ்வகை மூங்கிலை வளர்ப்பதற்கும், அதன் பின் பராமரிப்பு போன்றவற்றிற்கு ஏற்படும் செலவினங்களும், இவற்றை பிரித்தெடுப்பதற்கான செலவினங்களும், கள்ளிப்பட்டியிலுள்ள 6 வருட மூங்கில் தோட்டத்திலிருந்து கணக்கிடப்பட்டு அட்டவணை-27-ல் கொடுக்கப்பட்டுள்ளது. ஆறு வருட மூங்கில் தோட்டத்தை, ஏற்படுத்தவும், பராமரிக்கவும் ஆன மொத்த செலவு ரூ. 44,180.00. மூங்கிலை தோட்டத்திலிருந்து, வெட்டி பிரித்தெடுக்க ஆகும் செலவு ரூ. 1,08,125/-

இதனை விற்பதன் மூலம் கிடைக்கும் மொத்த வருவாய், ரூ. 2,31,500/- (சண்முகவேல் & பிரான்சிஸ் 1993)

ஒரு ஹெக்டேரில் 4, 5, 6 வருட மூங்கில்களிலிருந்து மொத்தமாக 10,750 மூங்கில் கழிகள் வெட்டப்பட்டன. வெட்டும்போதே, தோட்டத்தைச் சீரமைக்கும் பணியும் செய்யப்பட்டது. இவை அதிக எண்ணிக்கையில் புதிய கழிகளைத் தோற்றுவிக்க வழிவகுக்கும். வெட்டும்போது கிடைக்கும் கிளைகளானது, தனி விலையில் விற்கப்படுகின்றன. மூங்கில் தோட்டம் அமைத்து ஆறாவது ஆண்டில் வரவு, செலவு பார்க்கும்போது ரூ. 79,195/- நிகர லாபமாகக் கிடைக்கிறது. ஒரு ஹெக்டேரில் 5 ஆண்டுகளுக்குப் பிறகு, ஆண்டுதோறும், தோற்றுவிக்கப்படும் மூங்கிலின் எண்ணிக்கையானது, அதிகரித்துக் கொண்டே உள்ளது. கிடைக்கும் மூங்கிலின் பருமனும் பெரிதாகிக் கொண்டே உள்ளது. இவற்றை கணக்கில் கொண்டு பார்த்தால் வரும் ஆண்டுகளில் மூங்கிலின் விலையும் அதிகமாகும். எனவே கிடைக்கும் நிகர லாபமானது பின்வரும் ஆண்டுகளில் அதிகமாகும் என நம்பலாம். மூங்கிலின் வரவு/செலவு வகைகள் தொகுக்கப்பட்டு அட்டவணை-28-ல் கொடுக்கப்பட்டுள்ளது.

8.3.2. சிறு மூங்கில் : (டென்ரோ கேலமஸ் ஸ்டிரிக்டஸ்)

சிறு மூங்கில் தோட்டத்தை அடிப்படையாகக் கொண்டு ரெட்டி, 1990-ம் ஆண்டில் வெளியிட்ட வரவு/செலவு நிலவரம் கொடுக்கப் பட்டுள்ளது. மூங்கில் தோட்டத்தை அமைப்பதற்கும்/பராமரிப்பதற்கும் ஆன மொத்த செலவுகள் சுமார் ரூ. 30,000/- இவ்வகை மூங்கில்கள் பொதுவாக 30-40 ஆண்டுகளுக்கு ஒருமுறை தான் மலரும் தன்மை கொண்டவை. இதனை அடிப்படையாகக் கொண்டு மேலும் 6-ம் ஆண்டில் இருந்து 30-ம் ஆண்டுவரை பராமரிக்க ஏற்படும் செலவு மொத்தமாக சுமார் ரூ. 1,17,500/-. மொத்த செலவு ரூ. 1,47,500/-.

மூன்று ஆண்டுகளுக்குப் பிறகு, ஒவ்வொரு ஆண்டும், மூங்கில்கள் அறுவடை செய்வதற்கு ஏற்றதாக உள்ளது. 625 மூங்கில் திரள்களில், ஒரு ஹெக்டேருக்கு 6250 மூங்கில்கள் ஆண்டுதோறும் கிடைக்கிறது. சுமார் 5000 மூங்கில்களை விற்பதன் மூலமாக ஆண்டுக்கு ரூ. 35,000/- ஹெக்டேருக்கு கிடைக்கிறது. மொத்தமாக 30 ஆண்டுகளுக்குக் கணக்கிட்டுப் பார்க்கும் போது (20 சதவீதம் கழிவுக்குப் பின்னர்) கிடைக்கும் வருவாய் ரூ. 8,75,000 என மதிப்பிடப்பட்டுள்ளது.

எனவே மூங்கில் தோட்டம் அமைப்பது விவசாயப் பெருமக்களுக்கு மிகுந்த நன்மை பயப்பதாகவே இருக்கும் என்பதில் ஐயமில்லை. மூங்கில் வளர்ப்பு முறைகள், பராமரிப்பு முறைகள் இவற்றை விவசாயிகளுக்குத் தகுந்த முறையில் களப் பணியாளர்கள் மூலம் விவரிப்பது நாட்டின் பொருளாதார முன்னேற்றத்திற்கு அடிகோலும் என்பதில் ஐயமில்லை.

அட்டவணை - 27

மூங்கில் - வரவு, செலவு - ஒரு கண்ணோட்டம்

வயது (ஆண்டுகளில்)	மூங்கில் தோட்டம் அமைப்பதற்கும் பராமரிப்பதற்கும் ஏற்படும் செலவுகள் (ரூபாயில்)	மூங்கிலை வெட்டுவதற்கு ஏற்படும் செலவுகள் (ரூபாயில்)	மொத்த செலவுகள் (ரூபாயில்)	நிகர வருமானம் (ரூபாயில்)
1	11,400	-	11,400	-
2	6,750	-	6,750	-
3	5,145	-	5,145	-
4	6,415	30,000	36,415	56,250
5	6,320	25,125	34,445	60,500
6	8,150	50,000	58,150	114,750
	44,180	1,08,125	1,52,305	2,31,500

நிகர வருமானம் (செலவுகள் கழித்து) - ரூ. **79,195**

அட்டவணை - 28

6-ஆண்டு பெருமூங்கில் தோட்டம் வரவு-செலவு கண்ணோட்டம்

வயது (ஆண்டுகளில்)	செலவு (ரூபாயில்)	வரவு (ரூபாயில்)	தற்போதைய ரூபாய் மதிப்பு பல்வேறு தள்ளுபடி கண்ணோட்டத்தில்					
			செலவு (ரூபாயில்)	வரவு (ரூபாயில்)	செலவு (ரூபாயில்)	வரவு (ரூபாயில்)	செலவு (ரூபாயில்)	வரவு (ரூபாயில்)
			12%		14%		16%	
1	11,400	-	10,032	-	9,804	-	9.596	-
2	6.750	-	5,940	-	5.805	-	5,670	-
3	5,145	-	4,527		4.340	-	4,321	-
4	36,415	56,250	32,047	49,500	31,319	48,375	30,591	47,250
5	34,445	60,500	30,311	53,240	29,622	52,030	28,933	50,820
6	58,150	147,750	51,172	100,980	50,009	98,685	48,486	96,390
Total	1,52,305	2,34,500	1,34,029	2,03,720	1,30,899	1,99,090	1,27,657	1,94,460

தள்ளுபடி விகிதம். 12% = 1.51, 14% = 1.52, 16% = 1.52

அட்டவணை - 29

சிறு மூங்கில் தோட்டம் - வரவு - செலவு கண்ணோட்டம்

		ரூ.
1.	மூங்கில் தோட்ட அமைப்பு மற்றும் பராமரிப்பு செலவு	30,000
2.	மூங்கில் தோட்ட அமைப்பு மற்றும் பராமரிப்பு செலவு	1,17,500
	மொத்தம் செலவு	1,47,500
3.	மூன்று ஆண்டுக்குப் பிறகு ஒவ்வொரு ஆண்டும் அறுவடை செய்ய ஏற்றது, 625 மூங்கில் திரள்களில் ஹெக்டேருக்கு 6250 மூங்கில்கள் கிடைக்கின்றன. சுமார் 5000 மூங்கிலை விற்பதன் மூலம் ஆண்டுக்கு வருமானம்	35,500
4.	30 ஆண்டுகளுக்கு (20 சதவீத தள்ளுபடி) உள்பட	8,75,000

அத்தியாயம் - 9

உரமிடுதலும், அறுவடையும்

மூங்கில் மிக வேகமாக வளர்கின்ற தன்மையினாலும், எளிதாகக் கிடைப்பதாலும், நேராகவும், உயரமாகவும் இருப்பதாலும் பல்வேறு அன்றாடப் பணிகளுக்கு மூலப்பொருளாக பயன்படுத்தப்படுகிறது. இவை கிராமப்புறங்களில் வீடுகள் அமைப்பதற்கும், கூடைகள், கைவினைப் பொருட்கள் செய்வதற்கும், மேலும் பல்வேறு உபயோகங்களிலும் பயன்படுகிறது. எல்லாவற்றிற்கும் மேலாக காகித ஆலைகளில் மிக முக்கிய மூலப்பொருளாகப் பயன்படுகிறது. காகித ஆலைகள் 0.3 மில்லியன் மெட்ரிக் டன் செய்தித்தாள் அச்சிடும் கூழ், 0.196 மில்லியன் மெட்ரிக் டன் காகித கூழ் தயாரிக்கக்கூடிய அளவு கொள்கலன் அளவைக் கொண்டுள்ளன. இவற்றில் 316 சிறிய, மத்தியதர மற்றும் பெரிய காகித ஆலைகள் அடங்கும். இவை மொத்தமாக 2.75 மில்லியன் மெட்ரிக் டன் காகிதங்களையும், காகித அட்டைகளையும் ஒவ்வொரு ஆண்டிலும் உற்பத்தி செய்கின்றன. (அட்கோலி, 1992).

இந்த காகித ஆலைகள் நார் வகை மூலப்பொருள்கள் கிடைக்காமல் தற்போது பல்வேறு சிக்கல்களை சந்திக்கத் துவங்கியுள்ளன. இதுவரை மிக எளிதாக கிடைத்து வந்த, மிக முக்கிய மூலப் பொருளான மூங்கில்கள் கிடைப்பதில் கடும் தட்டுப்பாடு நிலவுகிறது. இருந்த போதிலும் இன்னமும், மூங்கில்களே 60 சதவீத மூலப் பொருளாகப் பயன்படுத்தப்படுகின்றன. தற்போதைய, மற்றும் எதிர்கால தேவைகளைக் கருத்தில் கொண்டு, மூங்கிலின் உற்பத்தியை அதிகரிக்கக் கூடிய நடவடிக்கைகளை எடுப்பதுடன், கிடைக்கக்கூடிய மூங்கிலைச் மிகவும் சிக்கனமாக கையாளுவது மிக முக்கியத் தேவையாகிறது (ரசாக் 1981). மூங்கிலை வெட்டும்போது சரியான வரைமுறை கையாளப் படுவதில்லை. அதற்குப் பதிலாக பல்வேறு வயது (ஆண்டுகள்)களுடைய மூங்கில்களை

ஒரே சமயத்தில் வெட்டி காகித கூழ் தயாரிக்கப் பயன்படுத்துகின்றனர். இந்த முறையில் நல்ல பண்புகளுடன் கூடிய கூழ் கிடைப்பதில்லை. இந்த முறையைப் போக்குவதற்காக பல்வேறு வகையான ஆராய்ச்சிகள் தற்போது மேற்கொள்ளப்பட்டு வருகின்றன. **மெலோகேனே பேக்கிபோரா, ஆக்டினிநேந்திரா நைக்ரோ சிலியேட்டா, டென்ரோ கேலமஸ் லாசூசிஸ்பேதஸ், பாம்பூசா டியல்டா, நியஹோதஸோ டுல்லோவா** என்ற சிற்றினங்களில் ரசாக் (1981) என்பவரும், **மெலோகேனா பெக்கிபோரா**, போஸ் (1988) என்பவரும், **டென்ரோ கேலமஸ் ஸ்டிரிக்டஸ்**, மகேஸ்வரி & சதுர்வேதி (1988) என்பவரும், **ஐய்ஜான்டிக்ளோ ஸ்கார்டெக்னி**, காசிம் (1992) என்பவரும், மற்றும் **பாம்பூசா பாம்போஸ்** சண்முகவேல் (1995) என்பவரும், எந்த ஆண்டில் மூங்கிலை வெட்டுவது காகித ஆலை கூழ்களைத் தயாரிப்பதற்குப் பயன்படும் என்பது மட்டுமின்றி, வேதிப் பொருள்கள் உபயோகம் போன்றவைகளைப் பற்றியும், பல்வேறு ஆராய்ச்சிகள் மேற்கொண்டு பரிந்துரைகள் செய்துள்ளனர். சண்முகவேல் (1995) மேற்கொண்ட ஆய்வுகளின் முக்கிய முடிவுகள் வருமாறு:

1. நார் மற்றும் கூழ்களின் தன்மைகள் ஒரு ஆண்டு முதல் 6 வயது வரை உள்ள மூங்கில்களில் பெரும்பாலும் ஒத்து காணப்படுகின்றன. கிடைக்கும் கூழ்களின் அளவு அதன் உயிர் எடையை (biomass) அடிப்படையாகக் கொண்டு காணப்படுகிறது. மொத்த உயிர் எடையின் மதிப்பு மூங்கில்களின் வயதை பொருத்து உள்ளது. இந்த முடிவானது மூங்கிலின் வயதுக்கும், அதிலிருந்து கிடைக்கும் நார் மற்றும் கூழ்களின் பண்புகளுக்கும் பெருமளவு வித்தியாசம் இல்லை என்பதைக் காட்டுகின்றன. எனவே மூங்கிலின் வயது என்பதை அறுவடைக்கு ஒரு காரணமாக எடுத்துக் கொள்ள முடியாது. (அட்டவணை 30 -32).

2. மூங்கிலின் வயது அதிகரிக்கும்போது, அதிலிருந்து கிடைக்கும் செல்லுலோஸ், லிக்னின், பென்டோசான், 1% சோடியம்

ஹைட்ராக்சைட் கரைவுகள், ஆல்கஹால் - பென்சின் கரைவுகள், குளிர் மற்றும் சுடுநீர் கரைவுகள், சாம்பல் அளவுகள் போன்ற பண்புகளும் அதிகரிக்கின்றன. (அட்டவணை -33).

3. வயது அதிகரிக்கும்போது, காப்பா எண்ணிக்கையை நிர்ணயிக்கக் கூடிய காரத்தின் அளவும் அதிகரிக்கிறது. கிடைக்கும் மொத்த கூழ்களின் அளவும் அதிகரித்திருக்கிறது. (அட்டவணை-34).

4. அமிலம், காரங்கள் நீக்கிய மற்றும் நீக்கப்படாத கூழ்களின் இயல்பியல பண்புகள் மற்றும் உறுதிப் பண்புகள் வயது அதிகரிக்கும் போது அதிகரிக்கின்றன. (அட்டவணை 35-38).

5. கிடைக்கும் கூழ்களின் சதவீத அடிப்படையில், பார்க்கும்போது 20 டன் மூங்கிலில், ஏறக்குறைய 8.7லிருந்து 9 டன் கூழ் கிடைப்பதாக கணக்கிடப்பட்டுள்ளது.

அட்டவணை - 30

பெருமூங்கிலில் நார்களின் நீளம்

வயது (ஆண்டுகளில்)	1	2	3	4	5	6
மூங்கிலின் கடினத்தன்மை (கி.கி.)	0.588	0.593	0.598	0.610	0.617	0.622
சராசரியாக நார்களின் நீளம் (மி.மீ.)	2.0	2.0	2.3	2.3	2.5	2.5
சிறுதுண்டுகளின் கடினத்தன்மை கி.கி/மீ^{3}	200.41	202.10	208.10	215.00	220.10	224.76

அட்டவணை - 31

நார்களின் வகைப்பாடு (சுத்திகரிக்கப்படாத கூழ்)

நார்களின் வகைப்பாடு	வயது (ஆண்டுகளில்)					
	1	2	3	4	5	6
+50% நார்கள்	68.10	68.90	69.10	69.80	69.96	69.96
+65% நார்கள்	7.44	8.10	8.42	8.92	8.92	8.92
+100% நார்கள்	3.72	3.74	3.80	3.83	3.83	3.83
-100% நார்கள்	18.88	18.96	19.00	19.09	19.09	19.10

அட்டவணை - 32

நார்களின் வகைப்பாடு (சுத்திகரிக்கப்பட்ட கூழ்)

நார்களின் வகைப்பாடு	வயது (ஆண்டுகளில்)					
	1	2	3	4	5	6
+50 நார்கள் %	76.10	78.20	79.12	80.27	80.40	80.70
+65 நார்கள் %	9.39	9.42	9.63	9.70	9.89	9.90
+100 நார்கள் %	5.10	5.24	5.40	5.42	5.50	5.51
-100 நார்கள் %	4.33	4.53	4.62	5.00	5.10	5.10

அட்டவணை - 33

தோட்டவகை மூங்கிலின் வேதித்தன்மைகள்

வயது (ஆண்டுகளில்)	சாம்பல் (%)	குளிர்நீரில் கரையக் கூடியவை (%)	சூடான நீரில் கரையக் கூடியவை (%)	ஆல்கஹாலில் பென்சீனில்கரையக் கூடியவை (%)	1%சோடியம் ஹைட்ராக்சைடில் கரையக்கூடியவை (%)	பென்டோசான் (%)	லிக்னின் (%)	செல்லுலோஸ் (%)	சுரப்பதும் (%)
1	1.20	4.00	4.47	7.50	20.50	19.10	28.00	60.01	40.0
2	1.50	4.00	4.60	7.50	21.90	19.32	28.50	61.20	40.0
3	1.70	4.20	4.90	7.90	22.50	19.53	29.00	62.50	45.0
4	1.90	4.20	5.10	8.00	23.00	19.62	30.50	63.30	50.0
5	2.10	4.30	5.80	8.00	23.00	20.33	31.50	64.50	50.0
6	2.30	4.50	5.95	8.00	23.50	20.20	32.00	65.60	50.0

அட்டவணை - 34

காகித கூழ் பற்றிய விபரங்கள்

தன்மைகள்	வயது (ஆண்டுகளில்)					
	1	2	3	4	5	6
மொத்த காகித கூழ் %	46.36	47.23	48.10	48.30	48.44	48.80
முடிச்சுகள் %	2.27	2.19	2.24	2.26	2.30	2.30
காப்பா எண்ணிக்கை	27.20	27.60	27.60	28.90	28.90	28.90

அட்டவணை - 35

சுத்திகரிக்கப்படாத காகித கூழின் இயற்பியல் பண்புகள்

தன்மைகள்	வயது (ஆண்டுகளில்)					
	1	2	3	4	5	6
வெடிப்பு பண்பு	47.8	48.0	48.2	48.9	49.0	49.1
கிழியும் தன்மை	80.0	82.0	84.0	85.0	86.0	86.5
முறியும் பண்பு	6706.0	6780.0	6990.0	7210.0	7822.0	7222.0
மடிப்பு திறன்	85.0	95.0	120.0	150.0	160.0	180.0

அட்டவணை - 36

காகித கூழ் சுத்திகரிப்பு தன்மைகள்

நார்களின் வகைப்பாடு	வயது (ஆண்டுகளில்)					
	1	2	3	4	5	6
துவக்க பண்பு (%)	30.0	30.0	32.0	33.0	33.0	33.0
இறுதிப்பண்பு(%)	75.0	76.0	78.0	80.0	80.0	84.0
குளோரைடு உபயோகம்	8.91	9.10	9.49	10.0	10.49	10.49
சுத்திகரிப்புக் கழிவு (%)	14.04	13.57	13.57	13.57	13.60	13.63

அட்டவணை - 37

சுத்திகரிக்கப்பட்ட காகித கூழின் பண்புகள்

தன்மைகள்	வயது (ஆண்டுகளில்)					
	1	2	3	4	5	6
வெடிப்பு பண்பு	37.5	38.0	42.5	42.5	43.5	44.0
கிழியும் தன்மை	63.9	64.9	66.7	68.0	68.9	68.9
முறியும் பண்பு	4933.0	5011.0	5316.0	5410.0	5415.0	5415.0
மடிப்பு திறன்	70.0	85.0	90.0	120.0	130.0	140.0

அட்டவணை - 38

காகித கூழ் கழிவு நீர் பண்புகள்

தன்மைகள்	வயது (ஆண்டுகளில்)					
	1	2	3	4	5	6
திடப்பொருட்கள் (கிராம்/லிட்டரில்)	200.00	205.1	206.0	208.0	209.0	209.0
அனங்ககப் பொருட்கள் %	46.90	47.69	47.67	48.10	48.33	48.33
அங்ககப் பொருட்கள் %	51.67	51.90	52.80	52.90	52.91	52.91
அமிலத்தில் கரையாதவை (கி/லிட்டரில்)	4.20	4.37	4.90	5.10	5.50	5.50
Na_2O	54.14	54.20	54.64	55.10	55.17	55.19
வீங்கும் பண்பு (மிலி/கி)	25.0	25.0	26.0	27.0	27.0	27.0
எரிபொருள் சக்தி (கலோரி/கிராம்)	3795.0	3810.0	3894.0	3910.0	3960.0	3968.0

இந்த ஆய்வுகளின் முடிவுகளிலிருந்து பார்க்கும் போது தோட்ட வகை மூங்கில்களின் வயது, மற்றும் வேதிப் பண்புகளில் குறிப்பிடத்தக்க மாற்றங்கள் ஏதும் காணப்படவில்லை. இந்த பண்பானது மூங்கில்கள் முதல் ஆண்டிலேயே (வயது) குறிப்பிடத்தக்க முதிர்ச்சி பெற்றுவிடுவதைத் தெளிவாகக் காட்டுகிறது. எனவே 1-6 வயதுடைய மூங்கிலை காகித கூழ் தயாரிக்க பயன்படுத்தலாம் என அறிய முடிகிறது. இருந்தபோதிலும், பின்வரும் ஆண்டுகளிலுள்ள மூங்கிலின் உற்பத்தியைக் கணக்கில் கொண்டு பார்த்து 36 மாதங்களில் வெட்டுவதற்கு பரிந்து செய்யப்பட்டுள்ளது. போஸ் 1988-ம் ஆண்டில் 21 மாதங்களில் **மெலோகேனா பக்கிபெரா** சிற்றினங்களை வெட்டுவதற்கு பரிந்துரை செய்தார். வருடத்தில் இரண்டு முறை வெட்டும் முறையை **டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்** சிற்றினத்திற்கு மோகன் (1981)-ல் பரிந்துரை செய்துள்ளா. யோதி (1985), சண்முகவேல் (1995) இருவரும் 36 மாதங்களில் மூங்கிலை வெட்ட பரிந்துரை செய்துள்ளனர்.

மேலே குறிப்பிட்ட ஆய்வு முடிவுகளிலிருந்து 36 மாதங்களில் மூங்கிலை வெட்டும் பரிந்துரை, பொதுவாக அனைவராலும் ஏற்றுக் கொள்ளப்பட்டு, பின்பற்றப்பட்டு வருகிறது.

9.1 உரமிடுதல் :

மூங்கில் வளர்வதற்கு அதிக அளவில் அனங்கக தனிமங்களை மண்ணிலிருந்து எடுத்துக் கொள்கின்றன. சரியான முறையில் உரமிட்டு பராமரிக்கப்படாத மூங்கில் தோட்டங்களிலிருந்து கிடைக்கும் மூங்கில்கள் எண்ணிக்கையிலும், தோற்றத்திலும், பண்புகளிலும் மாறுபட்டுக் காணப்படுகிறது. மூங்கில்களை அறுவடை செய்யும்போது அந்த இடத்திலிருந்து வெளியேறும் தனிமங்களை சமன்படுத்த, உரமிடுதல் மிக அவசியமாகிறது. யூதா (1960), மூங்கில் கழி, ரைசோம் இவற்றில் மேற்கொண்ட வேதிப் பகுப்பாய்விலிருந்து முக்கியமாக எந்த தனிமங்கள், எவ்வளவு உள்ளது எந்த நேரத்தில் தேவைப்படுவது, எந்த நேரத்தில் உரமிடுதல் போன்ற விவரங்களைத் தெரிவித்துள்ளார்.

9.2 மூன்று தனிமங்கள் :

பில்லோஸ்டேசிஸ் ரெடிகுலேடா, பிளியோபிளாட்டஸ் பியூப்சன்ஸ் சிற்றினங்களில் மேற்கொண்ட ஆய்விலிருந்து, நைட்ரஜன் என்ற தனிமத்தை அதிகமாகவும், அடுத்து பொட்டாசியம், பாஸ்பரஸ் தனிமங்களை உயிர் உடை (biomass)யில் கொண்டுள்ளது தெரிய வந்தது. இந்த மூன்று தனிமங்களும் சேர்ந்து முழுமையாக மூங்கிலின் வளர்ச்சியை துரிதப்படுத்துகின்றன. ***பிளியோபிளாஸ்டஸ் பியூப்சன்ஸ்*** சிற்றினத்தின், மூங்கில் தண்டு, கிளை, இலை பகுதியின் உயிர் எடையானது 0.8 தடவை நைட்ரஜன் உரமற்ற மூங்கில்களிலும், 1.5 தடவை பொட்டாசியம் உரமற்ற மூங்கில்களிலும், 2.9 தடவை 3 தனிமங்களும் இல்லாத மூங்கில்களிலும் குறைந்துள்ளது தெரியவந்துள்ளது. மூன்று தனிமங்களும் அளிக்கப்பட்ட மூங்கிலின் சைசோமின் வளர்ச்சியானது 2.5 தடவை அதிகரித்துள்ளது தெரிய வந்துள்ளது. மேலும் மூங்கில் தண்டு, ரைசோம் இவற்றில் பொட்டாசியம், நைட்ரஜனை விட மிக அதிக அளவில் இருப்பது தெரிய வந்தது. (அட்டவணை-39). ***பில்லோஸ்டேசிஸ் ரெடிகுலேடா***-வில் ஆண்டுதோறும் தோற்றுவிக்கப்படும் மூங்கிலை அடிப்படையாகக் கொண்டு பார்க்கும் போது 3 தனிமங்களையும் கலந்த உரமிடுவது அவசியம் என தெரிய வந்துள்ளது. (அட்டவணை-40).

9.3 உர அளவு :

மூன்று தனிமங்களையும் எந்த அளவில், எந்த விகிதத்தில் அளிப்பது பற்றிய ஆராய்ச்சிகள் பல்வேறு விஞ்ஞானிகளால் மேற்கொள்ளப்பட்டது.

பாட்டில் மற்றும் பாட்டில் (1988)-ல் அடுத்தடுத்த மூங்கில் களுக்குள்ள இடைவெளி மற்றும் உரமிடுதல் பற்றிய ஆராய்ச்சிகளை ***டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்*** சிற்றினத்தில் மேற்கொண்டனர். 1 x 1, 2 x 2, 3 x 3 மீ. இடைவெளிகள், மற்றும் இரண்டு வகையான உரமிடுதல் : 100 + 50 + 50 கிலோ கிராம் / 200 + 100 + 100 கிலோகிராம் /, என்.பி.கே. / ஹெ. முறைகள் கையாளப்பட்டன. 1 x 1 மீ-ல் 9.9, 2 x 2 மீ-ல் 6.5 மற்றும் 3 x 3 மீ-ல் 6.2 மூங்கில்களும் ஒரு திரளில் தோன்றியுள்ளதை

கணக்கிட்டுள்ளனர். மிக அருகில் நடப்பட்ட மூங்கில்கள் வளர்ச்சியின் அனைத்து நிலைகளிலும் மற்றவற்றைக் காட்டிலும் சிறப்பாக உள்ளதையும், உரமிடுவதில் ஆண்டுக்கு 100 + 50 + 50 கிலோகிராம் என்.பி.கே. / ஹெ. நல்ல பலன்கள் தந்ததையும் கணக்கில் கொண்டு இந்த அளவை பரிந்துரை செய்தனர். 3 வயதுடைய, ***டென்ரோகேலமஸ் அஸ்பர், தைரோஸ்டேகியா சியாமென்சிஸ், பேம்பூசா பேம்போஸ், டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்*** சிற்றினங்களில் தாய்லாந்தைச் சார்ந்த சுவன்னபின்னட் மற்றும் தயூஸ்டா, 1988-ம் ஆண்டு உரமிடுதல் பற்றிய ஆய்வுகளை மேற்கொண்டனர். மூங்கில் தோப்பை நான்கு பிரிவுகளாகப் பிரித்து, ஒரு பிரிவில் உரம் எதுவும் இடாமலும், மற்ற மூன்று பிரிவுகளில் முறையே 100, 200 மற்றும் 300 கிலோகிராம் / ஹெ. 15:15:15 என்பிகே உரமிட்டனர். இந்த ஆய்வுகளின் முடிவுகளிலிருந்து 100 கிலோகிராம் / ஹெ. உரமானது அறுவடைக்கும் பின்னர் இடுவது ***தைரோஸ்டேகியா சியாமென்சிஸ், டென்ரோகேலமஸ் அஸ்பர், பாம்பூசா பேம்போஸ்*** போன்ற சிற்றினங்களுக்கு ஏற்றது. ***டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்*** - சிற்றினத்துக்கு 200 கிலோகிராம் / ஹெ. ஏற்றது எனவும் கண்டறியப்பட்டு பரிந்துரையும் செய்யப்பட்டுள்ளது.

சீனாவைச் சேர்ந்த பியூ மயோயி (1988)-ம் ஆண்டில் ***பில்லோஸ்டேசிஸ் பியூப்சன்ஸ்*** சிற்றினத்திற்கு 375 கிலோகிராம்/ஹெ. என்:கே:பி. அறுவடைக்குப் பின் ஏற்றது என்ற முடிவையும், சண்முகவேல் (1995)-ல் 200 கிலோகிராம்/ஹெ. 15:15:15: என்பிகே. உரங்கள் ***பாம்பூசா பேம்போஸ்*** சிற்றினத்தில் அறுவடைக்குப் பின்னர் சிறந்த வளர்ச்சியை ஏற்படுத்தின என்ற முடிவையும் வெளியிட்டுள்ளனர்.

ஆகவே உரமிடுவது பற்றிய முடிவுகள் எதுவும் இன்னும் முழுமையாக பரிந்துரை செய்யப்படவில்லை. அவை இடத்திற்கு தகுந்தவாறும், காலநிலை, நிலவும் தட்பவெப்பம், மழையளவு, தோப்புகள் அளவு இவற்றைப் பொருத்து மாறுபடும் என்பது தெரிய வருகிறது.

அட்டவணை - 39

மூன்று தனிமங்களின் ஆய்வு முடிவுகள் *

ஆய்வின் ஒரு ஆண்டிற்குப் பின் மூங்கில் வளர்ச்சி			மூங்கில்				ரைசோம்				
உரமிடும் ஆய்வின் தன்மைகள்	புதிய மூங்கில் எண்ணிக்கை	அடிப்பருமன் (செ.மீ.)	சராசரி உயரம் (செ.மீ.)	இலைகளின் உயிர்எடை (கி)	மூங்கில்தண்டின் உயிர்எடை (கி)	குறியீட்டு எண்	மொத்த வளர்ச்சி(மி.மீ)	சராசரி பருமன்(செ.மீ.)	மொத்த உயிர் எடை (கி.)	குறியீட்டு எண்	புதிய மொட்டுக்கள் தோன்றியவை
இடத்தில் சரிஅளவு உரமிடுதல்	46	4.6	72	166	526	100	1877	5.9	745	100	40
நைட்ரஜன் இல்லாத உரம்	15	4.7	57	34	147	28	677	5.8	325	44	8
பாஸ்பரஸ் இல்லாத உரம்	16	4.7	74	49	215	41	810	5.7	325	44	11
பொட்டாஷ் இல்லாத உரம்	21	4.4	78	64	281	53	1005	5.3	405	54	20
எந்த உரமும் அளிக்காதது	17	3.8	63	46	182	35	774	5.0	288	39	8

* ஆய்வுக்கு எடுத்துக் கொள்ளப்பட்ட மூங்கிலின் பெயர் : பிளியோபிளாஸ்டஸ் பியூப்சன்ஸ்

அட்டவணை - 40

மூன்று தனிமங்களின் ஆய்வு முடிவுகள் *

உரமிடும் ஆய்வின் தன்மைகள்	எண்ணிக்கை				உயிர் எடை (கி.கி.)				சராசரி பருமன் (செ.மீ.)			
	முதல் ஆண்டு தோன்றியவை	குறியீட்டு எண்	இரண்டாம் ஆண்டு தோன்றியவை	குறியீட்டு எண்	முதல் ஆண்டு தோன்றியவை	குறியீட்டு எண்	இரண்டாம் ஆண்டு தோன்றியவை	குறியீட்டு எண்	முதல் ஆண்டு தோன்றியவை	குறியீட்டு எண்	இரண்டாம் ஆண்டு தோன்றியவை	குறியீட்டு எண்
இடத்தில் சமஅளவு உரமிடுதல்	36.0	100	33.0	100	162	100	156	100	4.95	100	5.25	10
நைட்ரஜன் இல்லாத உரம்	23.5	65	20.0	61	108	67	93	60	5.20	105	5.15	9
பாஸ்பரஸ் இல்லாத உரம்	30.5	85	26.0	79	147	91	102	65	5.25	106	4.45	8
பொட்டாஷ் இல்லாத உரம்	28.5	79	30.0	91	135	83	132	85	5.15	104	4.45	8
எந்த உரமும் அளிக்காதது	26.0	72	13.0	39	102	63	60	39	4.70	95	5.10	9

அத்தியாயம் - 10

சமுதாயக்காடுகளில் மூங்கில் - ஒரு அறிமுகம்

மூங்கிலின் பன்முக உபயோகத்தின் முக்கியத்துவத்தை அறிந்து, சமுதாயக் காடுகளின் பல்வேறு திட்டங்களில் மூங்கிலை வளர்ப்பதற்கு வனத்துறை, வனவியல் கழகம் போன்ற அமைப்புகள் நடவடிக்கை எடுத்துள்ளன. மிகப் பெரிய புல் வகையைச் சார்ந்த மூங்கிலை கிராமப்புற மக்கள், வீடுகளிலும், கிணறுகளைச் சுற்றிலும், வேளாண்மை நிலங்களிலும் வளர்ப்பதற்குத் துவங்கியுள்ளனர். சமுதாயக் காடு திட்டத்தின்கீழ் பல்வேறு நிலைகளில் மூங்கில் வளர்க்கப்படுகிறது. அவையாவன :

(1) சாலையோரத் தோப்புகள்

(2) பொதுநல வனயமாக்கும் முறைகள்

(3) வேளாண்காடுகள்

(4) அழிந்த வனங்களை சீரமைத்தல்

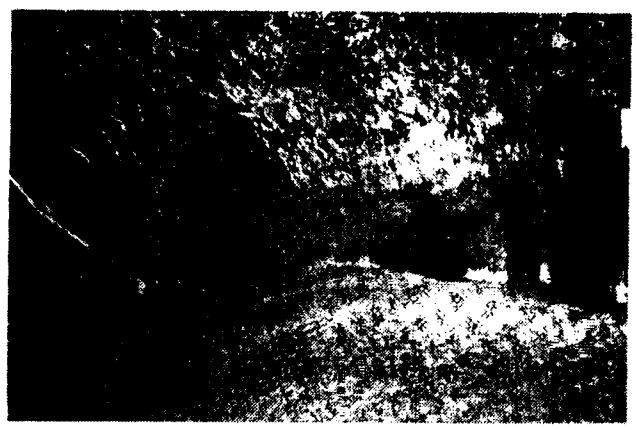
(5) தரிசுநில மேம்பாடுத் திட்டம்.

10.1 சாலையோரத் தோப்புகள் :

சாலையோரத் தோப்பு அமைத்தலின் மூலம், சாலைகளின் ஓரங்களிலும் வாய்க்கால் ஓரங்களிலும் சிறிய மூங்கில் தோப்புகள் அமைக்கப்படுகின்றன. இவ்வகை தோப்புகள் மண் அரிப்பைத் தவிர்ப்பதோடு நல்ல இயற்கைச் சூழலையும் அளிக்கின்றன. சாலையோரத் தோப்புகள் (படம் 18,19) பெரும்பாலும் அரசு நிலங்களிலேயே அமைக்கப்படுவதால் இவை வணிக ரீதியில் அதிக பலனை அளிப்பதில்லை. சாலையோரத் தோப்புகளின் அமைப்பில் பொதுமக்களை பங்கு பெறச் செய்வதன் மூலம், பாதி பலன்களை அவர்களும் பெறுமாறு வழிவகை செய்ய வேண்டும். அந்தந்தப் பகுதி மண் வகைகளுக்குத் தகுந்தவாறு சிற்றினங்களை வனத்துறை ஆராய்ச்சி மூலம் தேர்ந்தெடுத்து சரியான முறையில் பராமரிக்க ஏற்பாடு செய்ய

வேண்டும். மிக வேகமாக வளர்ச்சியடைகின்ற மூங்கிலானது மூன்று ஆண்டுகளில் அறுவடை செய்யும் அளவுக்கு முதிர்ச்சியடைந்து விடுகின்றன. கிராமப்புறங்களில் அங்கு வசிக்கின்ற மக்களே முக்கியமாக மூங்கிலை உபயோகித்துக் கொள்கின்றனர். அதாவது காகித ஆலை களுக்குக் கூட கிடைப்பது இல்லை. இவ்வாறு கிடைக்கும் மூங்கிலானது கிராமத்தில் இருக்கும் மக்களுக்கு கைவினைப் பொருள்கள், கடைகள் செய்தல் போன்ற வேலை வாய்ப்பினையும் செய்து தருகிறது. அதன் மூலம் பொருளாதாரத்தில் உயர வகை செய்கிறது. தமிழ்நாட்டில் வாய்க்கால் ஓரங்களில் பெருமளவு மூங்கில்கள் நடப்பட்டுள்ளன. (படம் - 20)

18. சாலையோர மூங்கில் தோப்புகள்
(திண்டுக்கல் – மதுரை சாலை)



19. சாலையோர மூங்கில் தோப்புகள்
தமிழ்நாட்டிலுள்ள வாடிப்பட்டி (மதுரை) கிராமத்தில்.

20. வாய்க்கால் ஓர மூங்கில்கள்

10.2 பொதுநல வனமயமாக்கும் திட்டம் :

பொதுநல வனமயமாக்கும் (Community Forestry) முறைகளை சண்முகவேல் 1995-ம் ஆண்டு விவரித்துள்ளார். பொதுநல வன மயமாக்கும் திட்டத்தின் மூலம் மூங்கிலை வளர்க்க ஊக்கவிக்க வேண்டும். கிராமப்புறங்களில் இருக்கும் பொது இடங்களில் மூங்கிலை வளர்க்கவும், பராமரிக்கவும் அந்த அந்த கிராம மக்களின் ஒத்துழைப்பைப் பெற வேண்டும். அதன்மூலம் கிடைக்கும் பலன்களை வனத்துறையும் பொதுமக்களும் 1:3 என்ற விகிதத்தில் பகிர்ந்து கொள்ள வேண்டும்.

பொதுவாக இந்தத் திட்டங்களின் கீழ் வனத்துறையினர் மண்ணைச் சீரமைத்து, மூங்கில் நாற்றுக்களை நட வேண்டும். அதன்பின் பராமரிக்கும் பொறுப்புகளை அந்த பகுதி மக்களில் குழுக்கள் அமைத்து அதன் மூலம் நிறைவேற்ற வேண்டும். இந்த திட்டமானது எந்த அளவுக்கு பொதுமக்களின் ஒத்துழைப்பு கிடைக்கிறதோ அதை பொருத்தே வெற்றி பெறுகிறது. இத்திட்டத்தின்கீழ் பங்குபெறும் குழுக்களில் அந்தப் பகுதியில் உள்ள படித்த வேலை வாய்ப்பில்லாத இளைஞர்களுக்கு முன்னுரிமை தர வேண்டும். மேலும் தேர்வு செய்யப்பட்ட குழுக்களுக்கு வன ஆராய்ச்சி நிறுவனங்களில் சரியான முறையில் மூங்கில் வளர்ப்பு பற்றிய பயிற்சி அளிக்க வேண்டும்.

முதலில் ஒவ்வொரு குழுக்களிலும் 25 பேர் மட்டுமே இருக்குமாறு பார்த்துக் கொள்ள வேண்டும். ஒவ்வொரு குழுவுக்கும் 25 ஹெக்டேர் நிலங்களை ஒளித்து, அவற்றில் மூங்கில் வளர்க்க ஏற்பாடு செய்ய வேண்டும். மேலும் பகிர்ந்தளிக்கப்பட்ட நிலங்களில் வனமாயக்குதலைத் தவிர இதர பணிகளுக்கு இந்த குழுவினர் பயன்படுத்தாமல் பாதுகாத்து வருவதில் வனத்துறையினர் முக்கிய பங்கு வகிக்க வேண்டும். எந்த வகையில் பலன்களை பகிர்ந்து கொள்ள வேண்டும் என்ற ஒப்பந்தத்தை வனத்துறையினரும், பொது மக்கள் குழுக்களும் முதலிலேயே செய்து கொள்ள வேண்டும். மேலும் மக்கள் குழுக்களின் பணிகளைக் கண்காணிக்க மாவட்ட வன அலுவலர், வனச்சரக அலுவலர், பொதுமக்கள் பிரதிநிதி இவர்களைக் கொண்ட குழுவை அமைக்க வேண்டும்.

10.3 வேளாண் காடுகள் :

இந்த திட்டத்தின் கீழ் வேளாண்மை பயிரும், காட்டு வகை மரங்களும், ஒரே நிலத்தில் ஒருங்கே வளர்க்கப்படுகின்றன. ஒவ்வொரு வேளாண்காடுகளும், (agro forestry models) ஒரு இடத்தின் அளவு, கிடைக்கின்ற சூரிய வெளிச்சம், தண்ணீர், மண்ணில் கிடைக்கும் தனிமங்கள், வேளாண்மை பயிர் மற்றும் காட்டு வகை மரம் இவற்றின் இடையேயுள்ள ஒருங்கிணைப்பு இவற்றைப் பொருத்து அமைக்கப்பட வேண்டும். இந்தியாவில் வேளாண்மைக் காடுகளின் கீழ் ஒருங்கே வளர்க்கப்படும் மூங்கில் சிற்றினங்களும், வேளாண்மைப் பயிர்களும் வருமாறு (திவிவேதி - 1994).

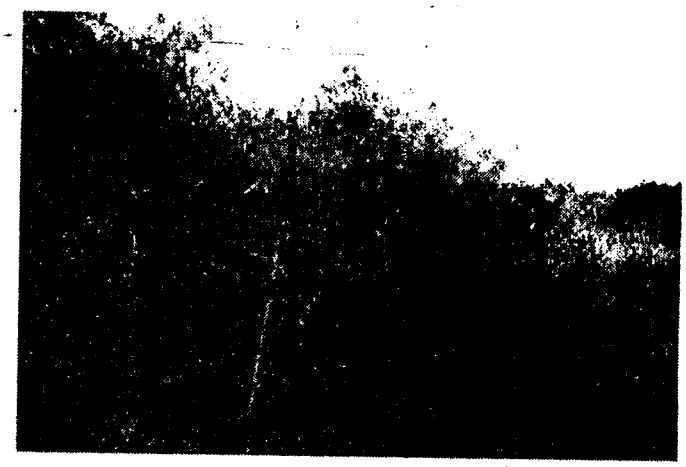
	வேளாண்மைப்பயிர்	மூங்கில் வகை
1) மத்திய பகுதி (Central region)	கோதுமை, நெல், சோளம், பலவகை தானியங்கள் எண்ணெய் வகை வித்துகள்	பல்வேறு வகை மூங்கில்கள்
2) தென்பகுதி (Southern region)	நெல், புகையிலை, மிளகாய், கரும்பு	டென்ரோ கேலமஸ் கெமில்டோனி
3) வடகிழக்குபகுதி	நெல்	டென்ரோ கேலமஸ் கெமில்டோனி

கோவை தமிழ்நாடு வேளாண்மைப் பல்கலைக் கழகப் பேராசிரியர் ஷேசாத்ரி, மூங்கிலின் ஊடுபயிராக சோயா பீன்ஸ்-சையும் வேளாண்காடுகள் திட்டத்தின் கீழ் ஒருங்கே பயிர் செய்து ஆய்வு செய்தார். இவரது முடிவுகள் முதல் ஆறு ஆண்டுகள் சோயாபீன்ஸ் மிகவும் நல்ல முறையில் உற்பத்தியாகி பலன்களை அளித்தது. அதன்பின் மூங்கிலின் கிளைகளைச் சீர் செய்வதன் மூலம் மேலும் பீன்ஸ் பயிராக்க முடியும் என்ற கருத்தையும் வெளியிட்டார்.

எனவே வேளாண்மைக் காடுகள் திட்டத்தின் மூலம் ஒரே நேரத்தில், ஒரே இடத்தில் இரண்டு வகைத் தாவரங்களை பயிர் செய்து, பொருளாதார முன்னேற்றம் காணலாம் என்பதில் ஐயமில்லை. மேலும் வாக் மற்றும் ராஜபட் -1991 -ல் மூங்கிலை மா, முந்திரி, பலா, ரப்பர் போன்ற தோட்டப்பயிர்களுக்கு (Horticulture) இடையே ஊடுபயிராகப் பயிர் செய்து வெற்றி பெற முடியும் என்ற விவரங்களை வெளியிட்டடுள்ளனர்.

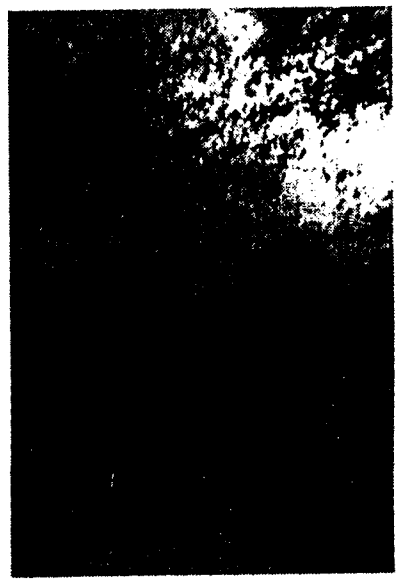
10.4 அழிந்த வனங்களைச் சீரமைத்தல் :

இந்திய வனவியல் புள்ளிவிவர அறிக்கை 1990 -ன்படி மொத்த வனப்பகுதி 75 மில்லியன் ஹெக்டேராகும். சமீபத்தில் எடுக்கப்பட்ட சாட்டலைட் படத்திலிருந்து 37.8 மில்லியன் ஹெக்டேரில் மட்டும், அடர்த்தியான வனப்பகுதியிருப்பதாகக் கண்டறியப்பட்டுள்ளது. மற்ற இடங்களில் வனப்பகுதி பெருமளவு அழிந்து காணப்படுவதுடன், மரங்களின் அடர்த்தி 40 சதவீதத்திற்கும் குறைவாகவே உள்ளது. மற்ற இடங்களில் எந்த விதமான மரங்களோ, இதர தாவர இனங்களோ காணப்படவில்லை. எனவே அழிந்த வனங்களைச் சீரமைக்கும் திட்டத்தின் கீழ் இந்த இடங்களில் மூங்கில்கள் அல்லது இதர மர வகைகளை நடச் செய்து, அவ்விடத்தில் இயற்கை உற்பத்தியை பெருக்க நடவடிக்கை எடுக்கலாம். இந்த திட்டத்தின் கீழ் பல்வேறு மாநிலங்களில் மூங்கில்கள் நடப்பட்டுள்ளன. (படம் - 21,22)



21. அழிந்த வனங்களைச் சீரமைத்தல்

22.A. அழிந்த வனங்களைச் சீரமைத்தல்



B. அழிந்த வனங்களைச் சீரமைத்தல்

10.5 தரிசு நில மேம்பாட்டு திட்டம் :

ஒரு இடத்தில் குறிப்பிட்ட அளவு உயர் எடை உற்பத்தி இல்லாமல் இருந்தால் அந்த இடமானது தரிசு நிலமாகக் கருதப்படுகிறது. இவ்விடமானது, சூழ்நிலை காரணமாக, தட்ப வெட்ப நிலையில் சமமற்ற நிலை, மண் அரிப்பு, அதிகமான கார, அமில தன்மை, வறட்சி, தண்ணீர் தேக்கம், மற்றும் அதிக பாறைகள் போன்றவற்றினாலும் பாதிக்கப் பட்டுள்ளது. இந்திய அரசாங்கம் இந்த வகை நிலங்களைச் சீரமைத்து, பயன் தரக்கூடிய தாவரங்களை அவ்விடங்களில் வளர்ப்பதற்கு ஏற்ற சூழ்நிலையை உருவாக்கி, உற்பத்தியை பெருக்கும் முறைகளை, தரிசு நில மேம்பாடத் திட்டத்தின்கீழ் ஏற்படுத்தியுள்ளது. தரிசு நில மேம்பாட்டுத் திட்டத்தின் கீழ் மூங்கிலையும் வளர்க்க ஆராய்ச்சிகள் செய்து,, பரிந்துரையும் செய்யப்பட்டுள்ளன. சுவகான் (1992), சுதுர்வேதி மற்றும் பாட்டியா (1993), பாட்டில் (1994) மற்றும் சண்முகவேல் மற்றும் பிரான்சிஸ் (1995) போன்ற ஆராய்ச்சியாளர்கள் தரிசு நில மேம்பாட்டுத்

திட்டத்தின் கீழ் மூங்கிலைப் பயிராக வளர்த்து, பலன் கிடைப்பதைக் கண்டறிந்து அறிக்கை வெளியிட்டுள்ளனர். (படம் - 23).

23. தரிசு நில மேம்பாடு திட்டத்தின் கீழ் நடவு செய்யப்பட்ட மூங்கில் திரள்கள்

அத்தியாயம் - 11

நோய் தாக்குதலும், கட்டுப்படுத்தும் முறைகளும்

மூங்கில், அறுவடைக்கு முன்னும், அறுவடையின் போதும், விதையைச் சேகரித்து வைத்திருக்கும் போதும் பாக்டீரியா, மற்றும் பூஞ்சாணம் தாக்கக் கூடும். எனவே விதைகளை செரிசான் (ceresan) போன்ற பூஞ்சாணக் கொல்லிகளுடன் ஒரு கிலோ விதைக்கு 4 கிராம் மருந்து என்ற அளவில் விதை நேர்த்தி செய்ய வேண்டும். விதை முளைப்புத் திறனை அதிகப்படுத்த பூஞ்சாளக் கொல்லி, ஜிப்ரலிக் அமிலம், பொட்டாசியம் ரைட்நேட் ஆகியவற்றுடன் விதைகளை முன் நேர்த்தி செய்யலாம்.

மூங்கிலில் வரும் வெக்கை நோய், அதிக கேடு விளைவிக்கக் கூடிய நோயாகும் இந்நோய் தாக்கிய பகுதிகளை நீக்கிவிட வேண்டும். பின்பு பாவிஸ்டின் (0.3%) ஃபிட்டோலான் (0.4%), டைத்தேன் எம் - 40 (0.4%) போன்ற ஏதாவது ஒன்றையோ, பாவிஸ்டின் 0.5% ஐயும், ஃபிடோலான் 0.3% ஐயும் கலந்தோ அல்லது பாவிஸ்டின் 0.5% ஐயும், ஃபியூரடான் 25 கிராமையும் கலந்து விசைத் தெளிப்பானில் தெளிக்கலாம். ஒரு தூருக்கு 3-4 லிட்டர் மேற்கூறிய கலவையை ஜூன் - ஜூலை மாதங்களில் தெளிக்க வேண்டும்.

பூச்சி தாக்குதல் :

மூங்கில் 40-க்கும் மேற்பட்ட பூச்சி வகைகளால் தாக்கப்படுகின்றது. பச்சை மூங்கில் அதிக அளவில் பூச்சி தாக்குதலுக்கு இலக்காகும். கிடங்குகளில் சேமித்து வைக்கப்பட்ட மூங்கிலையும், பத்து வகையான பூச்சியினங்கள் தாக்குகின்றன.

நோய் தாக்குதல், அறிகுறி, கட்டுப்படுத்தும் முறைகள் - ஆகியவற்றை கீழ் வருவன விளக்குகிறது.

11.1. இலைத்துளைப்பான், இலைச்சுருட்டுப்புழு : அறிகுறிகள் :

இலைகளில் ஏற்படும் துளைகள், இலைகளின் வடிவ மாற்றம்.

கட்டுப்படுத்தும் முறைகள் :

டிமிலின் - 25 (Dimilin - 25 w.p) 0.002% அல்லது சைபர் மெத்தரின் 0.002% (Cyper methrin 0.002%) அல்லது ஃபோலித்தியான் 0.2% (Folithion 0.2%) மருந்தை நீரில் கரைத்து இலைகளின் மீது தெளிக்க வேண்டும்.

11.2. தண்டுத்துளைப்பான், கணுத்துளைப்பான், அறிகுறிகள் :

தண்டு மடிதல், கணுக்களில் துளை ஏற்படுதல்.

கட்டுப்படுத்தும் முறைகள் :

டைமெத்தேயேட் 30 ஈசி 0.01% (Di-methodate 30 ec) அல்லது மோனோ குரோட்டோபாஸ் 36 ஈசி 0.2% (Monocrotophos 36 ec 0.2%) நீரில் கலந்து ஊசி மூலம் செலுத்தவும்.

11.3. சாறு உறிஞ்சும் பூச்சிகள், அறிகுறிகள் :

துளைகள் , மஞ்சள் நிற துகள்கள் திட்டுத் திட்டாகக் காணப்படும்.

கட்டுப்படுத்தும் முறைகள் :

சைபர் மெத்திரின் 0.4% (cyber methrin 0.4%) டீசலில் கரைத்து மூங்கில் முழுவதும் படும்படி தெளிக்க வேண்டும்.

அத்தியாயம் - 12

மூங்கில் தோப்பு அமைப்பதின் முக்கியத்துவம்

மூங்கில் அன்றாட வாழ்வின் உபயோகத்தில் பல்வேறு நிலைகளில் பயன்படுகிறது. இருந்த போதிலும் காகித ஆலைகளில் முக்கிய மூலப் பொருளாக உள்ளது. கடந்த பல்வேறு ஆண்டுகளாக காகிதம் மற்றும் காகித அட்டை தயாரிப்பில் பிற மர வகைகளைக் காட்டிலும் மூலப் பொருளாக அதிகமாகப் பயன்படுத்தப்பட்டது. தற்போது காகித அலைகளுக்கு மூக்கிய மூலப்பொருள் கிடைப்பதில் பெரும் சிக்கல் ஏற்பட்டுள்ளது. முக்கிய மூலப் பொருளாக இருந்து வந்த காட்டு மூங்கில் கிடைப்பது படிப்படியாகக் குறைந்து வருகிறது. இருந்த போதிலும் இன்னமும் மூங்கில் 80 சதவீத மூலப்பொருளாக இருந்து வருகிறது. தேசிய வேளாண்மைக் குழுவின் 1990-ம் ஆண்டின் அறிக்கையின்படி நடப்பு மூங்கில் தேவையானது 4, 724 மில்லியன் குயூபிக்க மீட்டரிலிருந்து, 2005-வது ஆண்டில் 7,005 மில்லியன் குயூபிக் மீட்டர் உயரக் கூடும். எனவே எதிர்பார்க்கும் தேவையான மூங்கிலைப் பெறுவதற்கு தகுந்த முறையில் நடவடிக்கை எடுக்க வேண்டும் எனவும் பரிந்துரை செய்துள்ளது. (அட்கோலி, 1990). அப்பரிந்துரையில் முக்கியமான ஒன்று மூங்கிலை மிக அதிகமான அளவில் பயிரிடுவது மட்டுமின்றி, இருக்கின்ற மூங்கில் வளத்தை திறமையான முறையிலும், சிக்கனமான முறையிலும் பயன்படுத்த வேண்டும் எனவும் குறிப்பிடப்பட்டுள்ளது.

12.1 காகித ஆலைகளின் தற்போதைய நிலை :

காகிதம் மற்றும் காகித அட்டை தொழிற்சாலைகளில் மூங்கில், எளிய, கடின வகை மரங்களை மூலப்பொருட்களாகத் தற்போது பயன்படுத்தி வருகிறது. மேலும் வோளண்மைக் கழிவுப் பொருட்களான மொலாசஸ், வைக்கோல், புல் வகைகள் போன்றவற்றை 30 சதவீதம்

மூலப்பொருளாகக் கொண்டு செயல்பட்டு வருகிறது. திட்டக்குழுவின் அறிக்கையின்படி வருடாந்திர காகிதங்கள் சார்ந்த பொருட்களின் தேவையானது நடப்பு - 2,754 மில்லியன் மெட்ரிக் டன்னிலிருந்து 2005-வது ஆண்டில் 4,250 மெட்ரிக் டன்னாக அதிகரிக்கும் என்பது தெரியவருகிறது. காகித வளர்ச்சிக் குழுவின் பூள்ளி விவரப்படி, இந்தியாவிலுள்ள காகித ஆலைகளின் கொள்கலன் அளவானது 01.01.1995 -ல் 0.3 மில்லியன் மெட்ரிக் டன், செய்தித்தாள் அச்சிடும் கூழ் வகையையும் மற்றும் 0.196 மில்லியன் மெட்ரிக் டன், ரெயான் வகை கூழ் வகையையும், மற்றும் 0.040 மில்லியன் மெட்ரிக் டன் காகித கூழ் வகையையும் தயாரிக்கக்கூடிய அளவு உள்ளது. இவற்றில் 67, 62, 379, மெட்ரிக் டன் / வருடம், காகிதம் மற்றும் காகித அட்டையை தயாரிக்கக் கூடிய சிறிய, மத்தியதர, பெரிய காகித ஆலைகள் சுமார் 315 அடங்கும், (அட்டவணை-41). தற்போது 75 ஆலைகள் மூடப்பட்டுள்ளன. இதன் மூலம் கொள்கலன் அளவானது 6.260 மில்லியன் மெட்ரிக் டன் குறைகிறது. (அட்டவணை-42). பல்வேறு காகித மற்றும் காகித அட்டை ஆலைகளின் உற்பத்தி விவரம் அட்டவணை-43 -ல் கொடுக்கப்பட்டுள்ளன.

அட்டவணை - 41

காகிதம் மற்றும் காகித அட்டை ஆலைகளின் கொள்கலன் அளவு (01.01.1990)

ஆலைகள்	குழுமம்	ஆலைகளின் எண்ணிக்கை	கொள்கலன் மெட்ரின் டன் / ஆண்டில்
செய்தித்தாள் அச்சிடும் கூழ்	-	5	3,00,000.00
ரேயான் வகை கூழ்	-	1	1,96,250.00
காகித கூழ்	-	-	40,000.00
செய்தித்தாள் அச்சிடும் கூழ்			
திறன் 10,000 - 20,000 மெட்ரிக் டன் வரை	II	30	14,57,300.00
5,000 - 10,000 மெட்ரிக் டன் வரை	III	24	37,91,000.00
2,000 - 5,000 மெட்ரிக் டன் வரை	VI	87	7,28,640.00
2,000-க்கும் குறைவானவை	V	107	3,61,720.00
மற்றவை		57	87,469.00
மொத்தம்		315	67,62,379.00

அட்டவணை - 42

மூடிய நிலையில் உள்ள காகித ஆலைகள்

குழுமம்	மூடிய ஆலைகளின் எண்ணிக்கை	கொள்கலன் மில்லியன் மெட்ரிக் டன் ஆண்டுக்கு)
I	9	0.316
II	4	0.061
III	13	0.109
IV	25	0.073
V	24	0.046
	75	6.260

அட்டவணை - 43

காகித ஆலைகளின் உற்பத்தித் திறன் *

ஆண்டு	எழுதும் காகிதமும்/ அச்சிடும் காகிதமும்	கவர் போன்ற பொருட்கள் செய்யும் காகிதம்	காகித அட்டை தயாரிக்க பயன்படும் வகை	சிறப்பான வகையைச் சேர்ந்த காகிதம்	மொத்தம்
1984	0.657	0.452	0.219	0.042	1.370
1985	0.720	0.495	0.240	0.046	1.501
1986	0.758	0.521	0.253	0.048	1.580
1987	0.806	0.554	0.269	0.051	1.680
1990	0.921	0.613	0.298	0.079	1.901

* எண்ணிக்கை மில்லியனில்

12.2 மூலப்பொருள்கள் :

வேளாண்மைக் கழிவுகளை 30 சதவீதம் மூலப் பொருட்களாக காகித ஆலைகள் கொண்டுள்ளது. தற்போதுள்ள தொழில்நுட்ப முன்னேற்றத்தை அடிப்படையாகக் கொண்டு, காகித ஆலைகள் பயன்படுத்தப்படும் வேளாண்மைக் கழிவுகளை 40 சதவீதமாக உயர்த்த முயற்சி செய்யப்பட்டுள்ளது. இருந்த போதிலும் காட்டிலிருந்து பெறப்படும் மூங்கில், யூகலிப்டஸ், சவுக்கு, மற்றும் பல்வேறு எளிய மற்றும் கடினவகை மரங்களை இந்த ஆலைகள் முக்கிய மூலப்பொருளாகக் கொண்டு உள்ளது. இந்தியாவில் இலையுதிர் காடுகளில் இயற்கையாகக் காணப்படும் மூங்கில்கள் இவற்றில் முக்கியமாக முதலிடம் பெறுகிறது. பெருமூங்கில், மற்றும் சிறு மூங்கில் வகைகளே பெருமளவு பயன்படுத்தப்படுகிறது. (சண்முகவேல் 1995).

12.3 மூலப்பொருட்களின் தற்போதைய நிலை :

தேசிய வேளாண்மைக் குழு முதன் முதலாக 1992-94 -ஆம் ஆண்டு களில் தொழிற்சாலைகளுக்குப் பயன்படும் மர வகைகள், இதர பணிகளுக்குப் பயன்படுத்தப்படும் மர வகைகள், அவற்றின் தேவைகள் இவற்றைப் பற்றிய புள்ளி விவரத்தை தயார் செய்தன. பின்னர் குறிப்பிட்ட கால அளவுக்குப் பின்னர் இந்த விவரங்களை மறு ஆய்வு செய்து தற்போதைய மூலப்பொருட்களின் தேவையானது, 2000 -வது ஆண்டில் ஒரு குறிப்பிட்ட இலக்கை எட்டக்கூடும் என்பதை பரிந்துரை செய்தது. இந்த விபரம் அட்டவணை-44 -ல் கொடுக்கப்பட்டுள்ளது. மத்திய அரசின் தொழிற்துறை நியமித்த காகித ஆலை வளர்ச்சிக் குழு, மூலப்பொருள்களின் தேவைகளைப் பற்றிய அறிக்கையை அரசுக்கு சமர்ப்பித்தது. அதில் 2000 -வது ஆண்டில் ஏற்படக்கூடிய மூலப்பொருள் பற்றாக்குறை தெளிவாகக் கொடுக்கப்பட்டுள்ளது. (அட்டவணை -45)

ஆகவே, இந்த இரண்டு குழுக்களும் செய்த பரிந்துரைகளையே ஏற்றுக் கொண்டதுடன், பற்றாக்குறையை சரிகட்டவும் அரசு முயற்சி எடுத்துள்ளது. அவற்றில் ஒன்றாக மூங்கிலை, வனவியலின் பல்வேறு திட்டங்கள் மூலம் வளரச் செய்வது, மூங்கில் தோப்பு அமைத்தல் போன்றவற்றை செய்து வருகிறது. மேலும் இதர மர வகைகளிலும் அவை காகித கூழ் தயாரிக்க ஏற்றவைதானா என்பன பற்றிய ஆராய்ச்சிகளும் பல்வேறு ஆய்வகங்களில் செயல்படுத்தப்பட்டு வருகிறது. இந்த ஆய்வு முடிவுகளிலிருந்து தெரிய வரும் மர வகைகளையும் வனத்துறையின் மூலம் வளர்க்கச் செய்ய ஏற்பாடு செய்யப்பட்டுள்ளது.

12.4 மூங்கில் வகைகளை தேர்வு செய்தல் :

காகித ஆலைகளிலுள்ள ஆராய்ச்சி மற்றும் வளர்ச்சி பிரிவின் மூலம் பல்வேறு வகை மூங்கில் சிற்றினங்களின் காகித கூழ் தன்மை பற்றிய ஆய்வுகள் மேற்கொள்ளப்பட்டன. கடந்த ஐந்து ஆண்டுகளாக மேற்கொள்ளப்பட்ட இந்த ஆய்வில், மற்ற ஆராய்ச்சி நிறுவனங்களும் உதவி புரிந்தன. இவற்றின் முடிவுகளில் இருந்து ***பாம்பூசா பேம்போஸ், பா. வல்காரிஸ், பா.டியூல்டா, டென்ரோகேலமஸ் ஸ்டிரிக்டஸ், டெ. ஹேமில்டோனி*** பரிந்துரையும் செய்யப்பட்டுள்ளது. (ஜான், 1994)

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தற்போதைய மரங்களின் தேவைகள்

மரவகை	1980-ல் தேவை	2000-ல் தேவை	பற்றாக்குறை
எரிமரம்	188.600	225.000	36.400
கட்டைகள்	22.720	46.755	24.035
காகிதக் கூழ்மரம்	4.175	17.695	13.520
மூங்கில்	4.274	7.005	2.731

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காகித ஆலைகளின் மூலப்பொருள் தேவைகள்

ஆண்டு	கொள்கலன் (மில்லியன் டன்)	காட்டுவகை மரங்களின் தேவைகளுடன் உற்பத்தி (மில்லியன் டன்)		உலர்ந்த மூலப் பொருட்கள் (மில்லியன் டன்)
		80%	70%	
1981	1.816	1.453	1.017	2.848
1986	2.200	1.760	1.232	3.450
1991	2.810	2.240	1.568	4.390
1996	8.500	2.800	1.960	5.488
2000	4.250	3.400	2.380	6.664

12.5 காகித ஆலைகளின் மூலம் மூங்கில் தோப்பு அமைத்தல் :

மத்திய அரசின், தொழில்துறையின் காகித வளர்ச்சிக் குழு, மூங்கில் தோப்பு அமைப்பதற்கான செலவுகள், பொருளாதார பயன்கள், பராமரிப்பு முறைகள் இவற்றைப் பற்றிய அறிக்கையை தயாரித்தது. தொழில் துறை அமைச்சகம், அனைத்து காகித ஆலைகளுக்கும் அனுப்பிய சுற்றறிக்கையில், அந்தந்த ஆலைகள் 2000 -வது ஆண்டுக்குள், தனக்குத் தேவைப்படும் மூலப்பொருட்களின் சுமார் 60 சதவீதத்தை, கிடைப்பதற்கு ஏற்பாடு செய்து கொள்ள வேண்டும் என்று தெரிவித்தது, இவற்றை மூங்கில், மற்றும் இதர மர வகைகளை வளர்ப்பதன் மூலம் எட்டலாம் எனவும் கருந்து தெரிவித்திருந்தது. மேலும் தங்கள் ஆலைகளுக்கு அருகிலுள்ள வனப்பகுதியில், வனமயமாக்குதல் திட்டத்திலும், வனத்துறையுடன் ஒத்துழைப்பு அளிக்க வேண்டும் எனவும் பரிந்துரை செய்தது, இதன் மூலம் 82.8 மில்லியன் ஹெக்டேர் நிலத்தில் வனமயமாக்குதல் (afforestation) திட்டத்தின் கீழ் மூங்கில் மற்றும் மர வகை தோப்புகளை அமைக்கலாம்.

மேலும் மூங்கில் மற்றும் இதர மரங்களில் இருந்த பெறப்படும் கூழ் வகையை ஆய்வு செய்து பார்க்கும் போது மூங்கில் மூலம் பெறப்பட்ட கூழ்களே பண்பில் சிறந்து விளங்கியது தெரிய வந்தது. (அட்டவணை-46) மேலும் கிடைக்கக் கூடிய கூழ்களின் சதவீதமும் மூங்கிலில் அதிகமாகக் காணப்பட்டது. இந்த ஆய்வுகளை சண்முகவேல் மற்றும் பிரான்சிஸ் 1995-ம் ஆண்டில் மேற்கொண்டனர்.

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தோட்டவகை மூங்கிலின் காகிதக் கூழ் தன்மைகளை - இதர கடின மர வகைகளுடன் ஒப்பிடுதல்

மூங்கில் மற்றும் மர வகைகள்	கூழ் தயாரிக்க காரங்களின்(Na_2O) தேவைகள்	காகிதக்கூழ் உற்பத்தி (சுத்திகரிக்கப்பட்டது)	இயற்பியல் பண்புகள்				காகிதக்கூழ் சுத்திகரிப்பு (ஒலோரைடு உபயோகம்%)	சுத்திகரிக்கப்பட்டது (%)	இயற்பியல் பண்புகள்			
			வெடிக்கும் பண்பு	உடையும் பண்பு	கிழியும் பண்பு (இடீ)	மடியும் பண்பு			வெடிக்கும் பண்பு	உடையும் பண்பு	கிழியும் பண்பு (இடீ)	மடியும் பண்பு
தோட்டவகை மூங்கில் (பெருமூங்கில்)	19	48.80	44.0	68.9	6.41	140.0	10.49	45.0	40.0	63.8	4.38	122.0
யூகலிப்டஸ் டெரிடி-கார்னிஸ்	19	43.65	40.5	56.7	6.20	178.0	9.61	38.5	37.4	51.5	4.89	160.0
அகேசியா டிகரன்ஸ்	20	54.32	33.2	48.3	6.20	130.0	7.51	49.3	30.4	2.3	5.10	110.0
அகேசியா அரேபிகா	22	50.62	38.7	52.5	5.90	160.0	8.08	47.0	33.5	40.5	3.21	140.3
எரித்ரோவியா சுபரோசா	20	49.65	34.7	47.8	5.90	265.0	10.85	39.3	30.3	41.5	4.20	249.0

தோட்ட வகை மூங்கில் மற்றும் இதர மர வகைகளில் கிடைக்கக்கூடிய கூழ் : [சதவிகித அடிப்படையில்] :

	சிற்றினம்	கூழ் (சதவிகிதம்)
1.	தோப்புவகை மூங்கில்	45.0
2.	யூகலிப்டஸ் டெரிடிகார்னிஸ்	38.5
3.	அகேசியா டிகரன்ஸ்	39.3
4.	அகேசியா அரேபியா	37.0
5.	எரித்ரோலியா சுபரோசா	39.3

முடிவாக, மூங்கில் தோட்டம் அமைக்க தேர்ந்தெடுக்கப்படும் மூங்கிலானது மிக வேகமாக வளரக் கூடியதாகவும், அதிகமான கூழை தரக் கூடியதாகவும் இருக்க வேண்டும். மேலும் அதிகமான ஆராய்ச்சிகள் மூலப் பொருள் சேமிப்பு பற்றியதாக இருக்கவேண்டும். ஆய்வுத் திட்டங்கள் முறைப்படி வடிவமைக்கப்பட்டதாக இருக்க வேண்டும். சரியான முறையில் நிதியை அளிப்பது அரசின் கடமையாகும். மூங்கிலை வளர்ப்பதன் முக்கியத்துவம், பொருளாதாரப் பயன்கள், அரசாங்கம் குறைந்த வட்டி விகிதத்தில் காகித ஆலைகளுக்கு மூங்கில், இதர மர வகை தோப்புகள் அமைக்க உதவி புரிய வேண்டும். கிடைக்கும் மூலப் பொருட்களை மிகச் சரியான முறையில் பயன்படுத்துவதாலும், நவீன விஞ்ஞான உத்திகளை கையாளுவதாலும், காகித ஆலைகளுக்கு மிகச் சிறந்த எதிர்காலம் உண்டு என்பதில் சிறிதும் ஐயமில்லை. (பாலாஜி 1992)

அத்தியாயம் - 13

மூங்கில் தோப்பு அமைப்பு : பிரச்சினைகளும், பலன்களும்

தற்போது மூங்கில் விவசாயிகள் தங்கள் அனுபவத்தின் பேரில் வளர்த்து வளர்கிறார்களே தவிர, விஞ்ஞானப் பூர்வமாக எந்தவித வளர்ப்பு முறைகளும் பராமரிப்பு வழி முறைகளும் பரிந்துரை செய்யப்படவில்லை. மூங்கிலை ஒரு வேளாண்மைப் பயிராக வளர்க்க விவசாய பெருமக்கள் தயங்குகின்றனர். மூங்கில் வளர்ப்பதில் ஏற்படும் நடைமுறைப் பிரச்சனைகளும், பலன்களையும் இப்பகுதியில் காணலாம்.

13.1 பிரச்சினைகள் :

மூங்கில் தோப்பு அமைக்கும் போது பல்வேறு பிரச்சனைகளை சந்திக்க வேண்டியுள்ளது. அவைகளாவன : விதை சேகரிப்பு, விதையிலா பெருக்கம், நிலத்தில் ஈரப்பதம், தாவர பாதுகாப்பு, களை, தீ, மூங்கில் திரள்களில் காணப்படும் சிக்கலான அமைப்பு போன்றவை.

1. விதை சேகரிப்பு :

மூங்கில் விதைகளானது நெல் அல்லது கோதுமையை ஒத்துக் காணப்படுவதோடு, மிகவும் எடையில் குறைந்தும் உள்ளது. இவற்றை நேரடியாக வனப்பகுதிகளிலிருந்துதான் சேகரிக்க வேண்டும். மூங்கில் மலர்வதில் காணப்படுகின்ற காலவரையற்ற தன்மையினால், விதை சேகரமும் அவ்வளவு எளிதல்ல. அப்படியே சேகரித்தாலும் அவை மிகக் குறைந்த காலங்களே உயிர் தன்மையுடன் (viability) உள்ளது. விதைகளை நீண்ட நாட்கள் சேகரம் செய்து வைப்பது பற்றிய ஆய்வுகள் நடைபெற்று வருகிறது.

2. விதையிலா பெருக்கம் :

பல்வேறு வகையான விதையில்லா பெருக்க முறைகள் கையாளப்பட்டு வருகின்றன. மூங்கிலை பல ஆண்டுகளாக வெட்டி,

கணுக்களில் வேர் உருவாகச் செய்து, கிளை, பதியன் போடுதல், திசு வளர்ப்பு முறைகள் போன்றவை சில முறைகள். விதையில்லாப் பெருக்க முறைகளில் உள்ள நன்மைகளையும், தீமைகளையும் பானிக் (1990) மற்றும் ஹாசன் (1980) வெளியிட்டுள்ளனர். மிகப் பெரிய தோட்டங்கள் அமைப்பதற்கு பெரும்பாலும் திசு வளர்ப்பு மூலம் பெறப்பட்ட நாற்றுகளே பயன்படுத்தப்படுகின்றன. ஆகையால் தோட்டம் அமைக்க எண்ணம் உள்ளவர்கள், அமைப்பதற்குத் தேவை மிக முக்கிய மூலப் பொருளான மூங்கில் நாற்றுக்கள் பெறுவதிலேயே பல்வேறு பிரச்சனைகளை சந்திக்க வேண்டியுள்ளது. எனவே வனத்துறையினர், மான்யத்துடன் கூடிய நிதியை அளிப்பதுடன். நாற்றுகளையும் மூங்கில் தோப்பு அமைக்க விரும்புபவர்களுக்கு அளித்து ஊக்குவிக்க வேண்டும்.

3. நிலத்தில் ஈரப்பதம் பாதுகாப்பு :

மூங்கில் வளர்வதற்கு நிலத்தின் ஈரப்பதம் இருப்பது மிகவும் அவசியம், ஆண்டுதோறும் உற்பத்தியாகும் மூங்கில் எண்ணிக்கை நிலத்திலுள்ள ஈரப்பதத்தை அடிப்படையாகக் கொண்டே தோற்றுவிக்கப்படுகிறது. ஆகையால் நிலத்தை எப்போதும் ஈரப் பதத்துடன் வைத்திருப்பது மிகவும் நன்று. ஆனால் எப்போதும் ஈரத்துடன் வைப்பது என்பது மிகவும் கடினமான ஒன்று. இது அந்த இடத்தில் உள்ள வெப்பநிலை, கிடைக்கும் நீர்வழி இவற்றைப் பொறுத்தது.

4. தாவர பாதுகாப்பு :

பல்வேறு பிரச்சனைகளைச் சந்திக்காமல் மூங்கில் தோட்டம் அமைப்பது என்பது இயலாத காரியம். மூங்கில் நாற்றுக்களாக. உள்ள நிலையில் எலி, பறவைகள், விலங்குகள் போன்றவற்றினால் பாதிப்பு அடைகின்றன. மிக முக்கியமாக குரங்குகளாலும், யானைகளாலும் பாதிப்பு ஏற்படுகிறது. ஆகவே தகுந்த முறையில் வளை அமைப்பது முக்கியமாகிறது. நாற்றங்காலில் மூங்கில் நாற்றுக்கள் உள்ள போது வலை பின்னலைக் கொண்டு பாதுகாப்பது அவசியமாகிறது. புதியதாகத்

தோற்றுவிக்கப்படும் மூங்கில் கழிவுகளை பூச்சிகள் பெருமளவு தாக்குகிறது. மூங்கில் மொட்டுக்களாக உள்ள நிலையில், அதாவது பூஞ்சைகளால் பாதிக்கப்படுகிறது. இதனைப் போக்குவதற்கு நீலகாப்பரை மூங்கில் திரள்களைச் சுற்றியுள்ள மண்ணில் தெளிக்க வேண்டும். மூங்கில் தகுந்த வளர்ச்சியை எட்டும் நிலை வரை இந்த முறை கையாளப்பட வேண்டும்.

5. களைகள் :

நாற்றுக்களை நட்ட சிறிது காலத்திற்குள் களைகளினால் பெருமளவு பாதிப்பு ஏற்படுகிறது. அதனால் தேவைப்படும் போது களை எடுப்பது அவசியமாகியறது. களைகளைச் சரியான முறையில் அகற்றாவிடில் மூங்கில் வளர்ச்சி பெருமளவு பாதிக்கப்படும்.

6. தீ :

காடுகளில் ஏற்படுகின்ற தியானது பெருமளவு மூங்கில்களின் வளர்ச்சியைப் பாதிப்பு அடையச் செய்கிறது. ஆகையால் தீ உருவாவதை தடுப்பதற்கான உறுதியான நடவடிக்கைகளைக் கையாள்வது முக்கியமாகும்.

7. மூங்கில திரள்களில் காணப்படும் சிக்கலான அமைப்பு :

மூங்கில் திரள்களில் உருவாகும் சில மூங்கில்கள் சிக்கலான அமைப்பைத் தோற்றுவிக்கின்றன. இதனால் மூங்கில் தோட்ட பராமரிப்பு கடினமாகிறது. (1) நிலத்தின் உறுதி தன்மை, (2) ரைசோம்களின் வளர்ச்சிக்கு நில ஆழமின்மை, (3) ஒரே பருவத்தில் அதிக எண்ணிக்கையில் ரைசோம்கள் உருவாகுதல். முதலாவது காரணத்தை அந்த இடத்தில் மேய்ச்சலைத் தடுப்பதன் மூலம் தவிர்க்கலாம். மூங்கல் திரள்களைச் சுற்றி மண்ணைக் குவித்து வைத்தல்மூலம் இரண்டாவது காரணத்தைக் தவிர்க்கலாம். மூன்றாவது காரணத்தை ஒரே பருவத்தில் அதிக எண்ணிக்கையில் தோற்றுவிக்கப்படுகின்ற போத்துக்களில் பெருமளவை நீக்குவதன் மூலம் தவிர்க்கலாம்.

13.2 பண்புகளும், பயன்களும் :

1. பொருளாதாரம் :

மூங்கிலை பயன்படுத்துகின்ற அடிப்படையில் இரண்டு வகையாகப் பிரிக்கலாம். (1) வணிக வகை மூங்கில் (commercial bamboo) (2) தொழிற்சாலைகளுக்குப் பயன்படும் மூங்கில். (Industrial bamboo) வணிக வகை மூங்கிலானது அனைத்து அன்றாடப் பணிகளுக்கும் பயன்படுத்துவது. இரண்டாவது வகை மூங்கில் காகிதம் மற்றும் காகித அட்டை தயாரிப்பதற்கு பயன்படுத்துவதாகும்.

வணிக வகை மூங்கில் விலையானது அதின் நீளம், பருமன் இவற்றைப் பொருத்து மாறுபடுகிறது. அதற்குத் தகுந்தவாறு விற்பனை செய்யப்படுகிறது. பொதுவாக விற்பனையில் உள்ள மூங்கிலின் அளவு வருமாறு.

பருமன் (சுற்றளவு)	நீளம் (மீ)	
9-12	3-5	(ஒவ்வொரு நீளப்பிரிவும் அனைத்துப்
12-15	5-7	பருமனையும் கொண்டுள்ளது)

தொழிற்சாலைகளுக்குப் பயன்படும் மூங்கிலை வனத்துறை, வனக் கழகம் போன்ற அமைப்புகளின் மூலம் நேரடியாக காகித ஆலைகளுக்கு விற்பனை செய்கின்றனர். பல்வேறு புள்ளியியலர்கள் மூங்கிலின் பொருளாதாரப் பயன்களைப் பற்றிய அறிக்கை தயார் செய்து விவரித்துள்ளனர். இவை அத்தியாயம் -ல் விவரிக்கப்பட்டுள்ளது. பொதுவாக தோட்டம் அமைத்த மூன்று வருடங்களுக்குப் பின்னர் பொருளாதார ரீதியில் நல்ல பலன்களை அளிக்கத் துவங்குகிறது.

2. வேலைவாய்ப்புகளைத் தோற்றுவித்தல் :

மூங்கில் பன்முக உபயோகப் பொருளாக இருப்பதாலும், இவற்றை காடுகள்/தோட்டங்களில் இருந்து அகற்றி எடுத்து வரவும், அதன்பின் பராமரிப்பதற்கும் பலதரப்பட்ட மக்களுக்கு வேலை வாய்ப்பினை ஏற்படுத்தி தருகிறது.

மூங்கில் தோட்டமானது, நேரடியாகவும், மறைமுகமாகவும் வேலை வாய்ப்பை ஏற்படுத்தி தருகிறது. நேரடி வேலை வாய்ப்பாக மேலாளர் ஆய்வக உதவியாளர், திட்டமிடுதல் மற்றும் அதனை செயல்படுத்துதல் போன்ற பணி நிலைகளை ஏற்படுத்தித் தருகிறது. ஒரு ஹெக்டேரில் உள்ள 500 மூங்கில் திரள்கள் 3.9 மனித வேலை நாட்களை பாமர மக்களுக்கும், 47.3 மனித வேலை நாட்களை மேலாளர் போன்ற பணிகளுக்கும் 30 வருடத்திற்கு தொடர்ந்து அளிக்கும். சுய வேலை வாய்ப்பாக பல்வேறு வேலை வாய்ப்பை ஏற்படுத்தித் தருகிறது.

3. பண்புகள் :

மூங்கிலின் ஊறுதி, அதன் விலை மதிப்பு ஆகியவற்றைக் கருத்தில் கொண்டு இதனை இயற்கை அளித்த வரம் எனக் கருதலாம். மூங்கிலின் உறுதியானது, அதன் இனம், வளரும் இடத்தின் தட்பவெப்ப நிலை, ஈர அடக்கம் ஆகியவற்றைப் பொருத்து அமைகிறது. மூங்கிலின் உதவியால் செய்யப்பட்ட பொருட்கள் வலிவுடனும், பொலிவுடனும் விளங்க மூங்கிலைப் பக்குவப்படுத்தல் (seasoning) அவசியமானது. இவ்வாறு பக்குவப்படுத்தப்பட்ட மூங்கில், பூச்சி, பூஞ்சான் தாக்குதல்கள் கையாளும் போது முறிதல் மற்றும் உடைதல் ஆகியவைகளுக்கு உள்ளாகாமல் இருக்கும். மூங்கிலில் விரிசல் விடுவதைத் தடுக்க பச்சையாக இருக்கும் போதே துண்டுகளாக ஆக்கிக் கொள்ளலாம். முதிச்சியடையாத மூங்கில் மென்மையானதாகவும், வளையும் தன்மை உடையதாகவும் உள்ளதால் விரும்பிய வடிவங்களில் (different shapes) பயன்படுத்தலாம். மூங்கிலில் மெருகேற்றவோ, சாயம் தீட்டவோ இயலும்.

மூங்கிலின் பல்வேறுபட்ட உபயோகங்களுக்கு கணுக்களின் வலிமை, எல்லா அளவுகளிலும் கிடைப்பது, உள்ளிடற்ற தன்மை, எளிதில் உபயோகப்படுத்தும் வகையில் இருப்பது, எடை குறைந்த அதே சமயத்தில் உறுதியான பண்பு, நேராகக் காணப்படும் தன்மை ஆகியவை காரணமாக அமைகின்றன.

வீடு கட்டவும், மரச்சாமன்கள் செய்யவும், வேளாண்கருவிகள் செய்யவும், மற்றும் ஏணி செய்தல், வேலி போடுதல், பாய் முடைதல், முறம் பின்னுதல் கட்டுமரம், அலங்காரப் பொருட்கள், விசிறி, குடை, பொம்மைகள், குழாய், தொப்பிகள், தட்டிகள் செய்யவும் பயன்படுகிறது. எறி ஈட்டிகள் செய்யவும், வாத்தியக் கருவிகள், பேனா, கூடாரக் கழிகள் செய்யவும் பயன்படுகிறது. மூங்கில் களி, தங்க நகைகள் செய்யப் பயன்படுகிறது. மூங்கில் விதை உணவாகவும், இளம் தளிர் ஊறுகாய்க்கும் பயன்படுகிறது. மூங்கிலின் விதை புரதச் சத்து நிறைந்தது.

மின் கலங்களிலும் இது பயனாகிறது. இறைச்சி சுடும் குச்சிகளாவும், பல் குத்தும் சிறு குச்சிகள் தயாரிக்கவும் மூங்கில் பயனாகிறது. விளையாட்டுத் சாமான்கள், தட்டுகள், புகை பிடிக்கும் குழாய்கள், தெளிப்பான்கள், சிலேட்டுகள் செய்யவும், தோணி கட்டவும், பூந்தொட்டிகள், கொடிமரம், மீன் பிடிக்கும் குச்சிகள், மீன் வலைகள், சீப்புகள், தொட்டில்கள், தூரிகைகள் தயாரிப்பதிலும் மூங்கில் பெரிதும் பயனாகிறது. (அட்டவணை-47), (படம் -24).

அட்டவணை - 47

இந்தியாவில் மூங்கில் உபயோகம்

(சதவீதத்தில்)

வரிசை எண்.	உபயோகம்	உபயோகம் (சதவீதத்தில்) (%)
1.	காகிதக் கூழ் தயாரிப்பு	35.00
2.	வீடு போன்ற கட்டுமானப் பணிகள்	20.00
3.	பந்தல் அமைப்பு போன்ற உபயோகம்	5.00
4.	கிராமப்புற உபயோகம்	20.00
5.	எரிபொருள் உபயோகம்	8.50
6.	கூடை தயாரிப்பு போன்ற உபயோகம்	5.00
7.	போக்குவரத்து உபயோகம்	1.50
8.	நாற்காலி போன்றவை செய்ய	1.00
9.	சிறு ஆலைகளின் உபயோகம்	1.00
10.	இதர உபயோகம்	3.00

24. மூங்கில் உபயோகம்

A. கூடை செய்தல்

B. பலதரப்பட்ட மூங்கில் கூடைகளும், தட்டிகளும்

C. பல்வேறு வகை கூடைகள்

D. ஏணிகளும், தட்டிகளும்

அட்டவணை - 48

மூங்கிலின் பொதுவான உபயோகங்கள்

உபயோகத் தன்மை	மூங்கிலின் பெயர்கள்
கட்டுமானப் பணிகள்	பாம்பூசா, பாலிமார்பா, பா. பால்கோவா, பா. பூளுமேனியா, டென்ரோகேலமஸ் மெம்ரேனஸ் டெ. லாஞ்சிஸ் பேதஸ் டெ. ஸ்டிரிக்டஸ் மேலேகேனா பெக்கிபெரா
பந்தல் மற்றும் மேற்கூரை அமைப்பு	பாம்பூசா பேம்போஸ், பே. டிபுல்டா, பே. பாரிமார்பா, டென்ரோகேலமஸ் ஸ்டிரிக்டஸ் கிம்னோ பேம்பூசா பால்கேடா
தடுப்புச் சுவர்	சைனோ பேம்பூசா எரிகன்ஸ்
தேயிலை தோட்டங்கள்	ஜீடோஸ்டேகியம் பாலிமன்பம்
நடை குச்சிகள்	அருண்டினேரியா அர்மேடா டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்
கடைகள் தயாரிப்பு	அருண்டினேரியா இன்டர்மீடியா, பாம்பூசா நியூட்டன்ஸ், பா. பல்லிடா, பா. பேம்போஸ், டென்ரோகேலமஸ் லாஞ்சிபேதஸ், தம்னோகேலமஸ் ஸ்பேதிபுளோரஸ்
வில் அம்புகள்	பாம்பூசா பாம்போஸ், டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்
சமையல் உபகரணம்	ஸ்செபலோஸ்டேகியம் பெர்கிரசில்
விவசாய உபகரணம்	டென்ரோகேலமஸ் ஸ்டிரிக்டஸ், அக்லேண்ட்ரா டிரவன்கோரியா,
அலங்காரப் பொருட்கள்	டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்

உபயோகத் தன்மை	மூங்கிலின் பெயர்கள்
வேலி அமைப்பு	இன்டோகேலமஸ் வெய்டியனஸ்
மீன் பிடிக்க	அருண்டினேரியா அமாபிலிஸ், சிம்னோபேம்பூசா பால்கேடா டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்
பட்டு வளர்ப்பு	பாம்பூசா பேம்போஸ், டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்
கதவுகள் மற்றும் ஜன்னல் அமைப்புகள்	பாம்பூசா பேம்போஸ், டைனோஸ்டேகியம் கிரிப்தி, டென்ரோகேலமஸ் ஹீக்கரி.
பொதுவான உபயோகம்	பாம்பூசா பேம்போஸ், டென்ரோகேலமஸ் ஸ்டிரிக்டஸ்,
இசைக் கருவிகள்	டென்ரோகேலமஸ் ஸ்டிரிக்டஸ், அருண்டுனேரியா சிற்றினங்கள்.
அழகு மூங்கில்கள்	பாம்பூசா வர்காரிஸ், செலபலோஸ்டேரியம் பெர்கிரசில்
படகு தயாரிப்பு	பாம்பூசா பேம்போஸ்.

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FOREWORD

Every year, 25 billion tons of top soil are lost from farm land by erosion. Forests are vanishing at the rate of 16.8 million hectares a year. Deforestation deprives poor people, of fuel wood and produces its own environmental refugees. Deforestation in the hills causes avalanches and flooding in the plains during monsoon. When the Himalayas were covered with forests, Bangladesh suffered a major flood about twice in a century– now the frequency is one in four years. Deforestation is also responsible for addition of 33 per cent of CO_2 to the atmosphere (5.5 billion tons each year) which contributes to global warming. Forests are deemed to be **"global sinks"** for CO_2, and loss of forest cover raises CO_2 level in the atmosphere. Forests prevent soil erosion and provide one of nature's principal means of water management. Therefore, scientific forest management is a high priority area.

The forestry research in India has by now a history of more than a century. Outstanding work has been done in the past. However, current knowledge and pattern of research that lack sound basis in biological knowledge will not result in, sufficiently accurate predictions of the consequences of potentially harmful influences on forest-management practices. The deficiency will reduce our ability to maintain or enhance forest productivity, recreation and conservation as well as our ability to ameliorate or adapt to changes in the global environment.

To help overcome this unfortunate deficiency in knowledge, a new research paradigm: an environmental paradigm will need to be adopted. This will help the forestry research to increase the breadth of research areas covered and the depth to which they are investigated. To achieve this Dr. P. Shanmughavel have made an attempt to put together several important research guidelines. I hope, this book will serve to further the cause of Forestry in general and Forestry Research in particular.

(Prof.Dr.S.KANNAIYAN)

PREFACE

The forestry research in India has by now a history of more than a century. Outstanding work has been done in the past. However, current knowledge and pattern of research will not result sufficiently in accurate predictions of the consequences of potentially harmful influences on forest-management practices that lack a sound basis in biological knowledge. The deficiency will reduce our ability to maintain or enhance forest productivity, recreation and conservation as well as our ability to ameliorate or adapt to changes in the global environment. To help overcome this unfortunate deficiency in knowledge, a new research paradigm will have to be adopted an environmental paradigm. This will require forestry research to increase the breadth of research areas covered and the depth to which they are investigated. To achieve this, an attempt has been made to bring out this forestry research manual, which encompasses several important research guidelines and I hope, this manual will serve to further the cause of Forestry in general and Forestry Research in particular.

Coimbatore

P. Shanmughavel

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1

PRODUCTIVITY STUDIES

1.1 INTRODUCTION

Forests have traditionally been used for many products, including timber, fuel and fodder. Determining the biomass of forests is a useful way of providing estimates on the quantity of these components. Typically volume estimations have assessed the quantity of saw timber, but this ignores the other useful components such as smaller size wood for fuel use. Furthermore, very few to none assessments have been made of the quantity of wood present in forests that appear to have no potential for saw timber production. The total above ground biomass of forests, which is defined as biomass density when assessed, may be expressed as dry weight per unit area and is a useful way of quantifying the amount of resource available for all traditional uses. It either gives the quantity of total biomass directly or the quantity of each component (e.g., leaves, branches and bole) because their biomass tends to vary systematically with the total biomass. However, the biomass of each forest component depends on the forest type, such as natural or planted forests and closed or open forests. For example, leaves for fodder are about 3-5% and merchantable bole is about 60% of the total above ground biomass in closed forests.

The quantity of biomass in a forest is the result of the difference between production through photosynthesis and consumption by respiration and harvest processes. Thus it is a useful measure for assessing changes in forest structure. Changes in forest biomass density are brought about by natural succession, human activities such as silviculture, harvesting, and degradation; and natural impacts by wildfire and climate change. Biomass density is also a useful variable for comparing structural and functional attributes of forest ecosystems across a wide range of environmental conditions.

Biomass of forests is also very relevant for issues related to global changes. For example, the role of tropical forests in global bio-geochemical cycles, especially the carbon cycle and its relation to the greenhouse effect, has kindled interest in estimating the biomass density of tropical forests. The biomass of forests provides estimates of the carbon pools in forest vegetation because about 50% of it is composed of carbon. Consequently, biomass represents the potential amount of carbon that can be added to the atmosphere as carbon dioxide when the forest is cleared or burnt. Attempts to estimate the biomass density of tropical forests have been made by the scientific community for use in models that assess the contribution of tropical deforestation and biomass burning in the increase of atmospheric carbon dioxide and other trace gases (Brocon et al.1989, Brown and Iverson, 1992, FAO, 1993).

Global interests in climate change led to the establishment of the UN Framework Convention on Climate Change (UNFCCC) at the 1992 UN conference on Environment and Development (UNCED). Over 130 nations have ratified this convention, which means that these nations need to make national greenhouse gas emission inventories. Changes in the cover, use, and management of forests produce sources and sinks of carbon dioxide to and from the biosphere. To estimate the magnitude of these sources and sinks, requires reliable estimates of the biomass density of the forests undergoing change.

Biomass density estimate also provides the means for calculating the amount of carbon dioxide that can be removed from the atmosphere by rejuvenating forests or by plantations, because they establish the rates of biomass production and the upper bounds for carbon sequestering.

This issue is receiving more attention of late as countries look to forests as a means of mitigating greenhouse gas emission, particularly carbon dioxide, a major greenhouse gas and the one fixed during photosynthesis. Practices such as sustainable forest management slow down deforestation and low impact logging decrease carbon dioxide emissions and conserve it. Other practices such as plantation establishment or other tree planting programs on previously non-forested land sequester carbon dioxide (Brown et al.1996). Furthermore, biomass density estimates of forests are extremely relevant for studying other global bio-geochemical cycles, such as nitrogen, because the amount of other nutrient elements in forests is also related to the quantity of biomass present.

Another issue related to forest biomass has emerged since the 1980s. In addition to loss of forest area, forest degradation, resulting in biomass density loss, is known to be occurring (Brown et al., 1994, FAO 1993, 1995). Much of this biomass degradation appears to be unrecorded; this is in addition to that accounted for by sanctioned harvesting. An example is the illegal logging practices occurring in many forests of tropical Asia (Callister 1992). Clearly, this process of biomass density reduction has implications on the global carbon cycle, other bio-geochemical cycles, and biodiversity. Biomass degradation is due to many factors mostly related to social, economic and political factors.

1.2 WHAT IS BIOMASS?

To address many of the issues raised above related to forest biomass, we need to estimate all of forest components, including the above-ground and below-ground living mass of trees, shrubs, palms, saplings, other under storey components that change with time and with natural and human disturbances. However for practical reasons, this methodology is restricted to the following component of biomass density: the total amount of live above-ground organic matter present in trees including leaves, twigs, branches, main bole, and bark. The biomass of these components generally accounts for the greatest fraction of total living biomass in a forest and does not pose too many logistic problems in its estimation. Consequently, biomass is defined as the total amount of above-ground living organic matter in trees expressed as oven-dry tons per unit area (tree, hectare, region or country). It is referred to as

biomass density when expressed as mass per unit area, e.g., tons per hectare. The total biomass for a region or country is obtained from the product of biomass density and the corresponding area of forests.

For most forests or tree formations, biomass density estimates will be based only on the biomass in trees with diameters greater than or equal to 10 cm, which is the usual minimum diameter measured in most inventories of closed forests. However, for forests or trees of smaller stature, such as those in the arid or montane zones, degraded forests, or secondary forests, lower minimum diameters should be chosen.

Woody biomass for many traditional uses does not fully originate from forests; significant quantities are obtained from non-forest lands such as small woodlots, windbreaks, other tree line formations, home gardens, etc.

1.3 METHODOLOGY

1.3.1 Woody vegetation

The desired information is the above -ground woody biomass, but since it is seldom practical to measure this directly, an indirect approach using the stem basal area (m^2) and height (m) of a sample of woody plants is used. In order to extrapolate the sample to a per hectare basis, the total basal area per species per hectare (m^2/ha) and the plant density (plants/ha) are also required.

1.3.2 Species

Species should be identified by their full scientific name (Genus, species, Author). Unidentified species should be given a code or local name, and a reference to a specimen in a herbarium.

In natural communities with a large number of species, it is not necessary to record the height and basal area of minor species individually. All the species contributing less than 10% of the total biomass can be combined into one category.

In extremely diverse communities with no clear biomass dominance, where no species contributes more than 10% to the total biomass, it may be necessary to define the 'species' on a functional basis; for instance emergent, canopy trees, sub-canopy trees and under storied shrubs, recording which species were placed in which category.

If the trees are sparse, then all the trees within the study site can be individually counted and measured. Usually this is not the case, and one or more sub samples each including about 100 trees is taken.

A square quadrat of known area can be laid out with the aid of a tape measure, a compass and string, but often a circular quadrat (all the trees within a given distance of a center peg) is easier to work with.

A long thin quadrat (belt transect) is often an efficient method in dense vegetation. Lay out a measuring tape (50 m) in a straight line, and record all the trees within a given distance (1-5 m, measured with a hand-held rod) on either side of the tape. Both the length and width of transect can be varied to give a total sample of about 100 plants; different widths can be used for common shrubs and sparse trees within the same sample. Individuals (or multi stemmed clumps) more than half within the plot boundary should be counted in. To permit biomass estimates based on individual trees at a later stage, data should be recorded as in the following example:

Plots are 5 m × 50 m

Species	Height (m)	Diameter (cm)	Stem area (cm^2)
Burkea african	3.2	15	176
Ochoa pulchra	1.5	5	19
Sclerocarya birrea	6	30	707

1.3.3 Stem density: (i) Plotless methods

Laying out plots is time consuming and can lead to error due to subjective placement of the plots. A variety of plotless method is available, such as the Point-Center-Quarter method (PCQ; Cottam and Curtis, 1956). These methods use the distance between random points and the nearest plant to calculate an average inter-plant distance (d_X). The number of plants per hectare (N) is then given by

$$N = 10{,}000 / d_x 2$$

where d_X is in meters.

About 100 distance measurements are required, and at the same time the species, stem diameters and heights of this random sample of plants are recorded.

The PCQ method is not applicable to vegetation, which is regularly spaced (such as plantations) or highly clumped; various modifications, such as the two-distance methods of Diggle (1975) or Cox (1975) must be used for this purpose.

1.3.4 Height

Height is the vertical distance between the ground and the highest living part. For trees taller than 5 m an estimate to the nearest meter is sufficient; smaller trees should be recorded to the nearest 0.1 m. A measuring rod is the easiest method in low vegetation. In tall vegetation, where the top and the bottom of the tree can be simultaneously observed, clinometers can be used; otherwise any practical method can be applied.

The mean maximum height for each vegetation layer (stratum) should be estimated from the data. For example, for a primary tropical lowland forest the emergent may reach 60 m, the canopy trees 40 m, the sub canopy trees 20 m and the under storey shrubs 6 m.

1.3.5 Stem basal area

The stem basal area (A) is the cross-sectional area of the trunk (m^2) measured at the lowest point not influenced by basal swellings or buttresses. In forests it is traditionally measured at 1.3 m above ground level ('diameter at breast height', DBH), but in tropical forests the trees may still be buttressed at this height, and in savannas, branching frequently occurs below this height. The area can be calculated either from a diameter (d) measurement using calipers, or from a circumference (c) measure using a tape.

$$A = 0.7854\ d^2 \text{ or}$$

$$A = 0.0796\ c^2$$

The result will be in m^2 if the diameter and circumference are measured in m; if measured in cm, divide the answer by 10,000 to convert cm^2 to m^2. If the stems are very markedly non-cylindrical (for instance if they are eliptical or convoluted) an empirical correction factor should be calculated.

Where a single plant has more than one stem, the area of each stem should be measured. For shrubs with very many small stems an estimate of the total combined area is adequate.

The total stem basal area for the plot is calculated by multiplying the stem basal area by stem density for each species (according to the criteria for species as defined above).

1.4 TREE BIOMASS ESTIMATION: NATURAL VEGETATION

Cutting and weighing all portions of a tree estimates most precisely tree biomass. As this is very time consuming, tree biomass is more commonly estimated by statistical means, eg. by sub sampling, or on estimates based on tree attributes. When sub sampling is not possible, biomass is most commonly estimated from a regression equation.

Since mass is the product of volume and density, tree biomass regressions often use diameter at breast height (DBH, cm), total height (H, m) and some measure of specific wood density (S, t/m^3). A locally developed equation is generally most reliable and should be used whenever possible. When no local equation is available, one of the regression equations given below can be used. These have been derived from several data sets and rigorously tested for reliability (Brown et al., 1989). Equations using D, H and S are the most reliable, followed by those using D and H, or just D. When H is not available one may apply double sampling methods, and estimate H as a function of D, then biomass as a function of D and estimate H. This is better than other approaches based on D alone when the H-D relationship accurately reflects the population of interest.

The regression relationships vary slightly with climate, so there are three equations reflecting three rainfall regimes: dry < 1500 mm, moist 1500-4000 mm and wet > 4000 mm. Not all equations are available for all climate types; due to lack of reliable data.

Equations may be applied to individual trees, mean trees or stand tables (numbers of stems per size classes) to estimate total above -ground biomass for a given tree, for a mean tree or per unit area respectively (Wharton and Cunia, 1985).

The following equations estimate biomass (B kg) and total height (H m) for trees in tropical forests. Values for the sample size, n, and goodness of fit, R^2 (an adjusted R^2) are included. The non-linear models include the adjustment term (MSE/2) together with the intercept, when appropriate.

1.5 TREE BIOMASS ESTIMATION: EVEN-AGED PLANTATIONS

Woody biomass estimation in even-aged plantations is simpler than in natural forest, and requires destructive sampling of many trees. The same principle of estimating biomass from predictor variable such as stem cross-sectional area and height, applies, but the model relating these variables to biomass cannot be assumed to be the same for different species and trees of different sizes.

For many species, for a given stand structure, the following linear function gives an accurate prediction of biomass (Stewart et al., 1992);

$$W = a_{ij} + b_{ij} \quad \Sigma d^2$$

Where, W= biomass; D= stem diameter (Σd^2 being the sum of the squared diameters of all the stems of a multi stemmed tree); a and b are coefficients for species i on site j.

These coefficients have to be determined separately for each species and each site.

Forest type		n	R^2_{adj}
Dry	$B = 34.4703 - 8.0671\ D + 0.6589\ D^2$	32	0.67
	$H = \exp\{(0.671) + 0.6301\ \ln D\}$	1231	0.54
Moist	$B = 38.4908 - 11.7883\ D + 1.1926\ D^2$	1680	0.78
	$B = \exp\{-3.1141 + 0.9719\ \ln (D^2H)\}$	168	0.97
	$B = \exp\{-2.4090 + 0.9522\ \ln (D^2HS)\}$	94	0.99
	$H = \exp\{1.0710 + 0.5677\ \ln D\}$	3824	0.61
Wet	$B = 13.2579 - 4.8945\ D + 0.6713\ D^2$	69	0.90
	$B = \exp\{-3.3012 + 0.9439\ \ln (D^2H)\}$	69	0.90
	$H = \exp\{1.2017 + 0.5627\ \ln D\}$	69	0.74

It should be stressed that although these equations have been derived from large (and sometimes very large) sample sizes, they should be viewed with some caution until validated for a given system.

Procedure

1. Fell a minimum of 12 trees.
2. Partition the trees into components (wood of different sizes, levels, and pods/fruit).
3. Weigh the components immediately in the field.
4. Oven dry sub samples (>100 g) of each to determine water content.
5. Calculate total dry weight (biomass);

The biomass and diameter(s) of the sample trees are used to determine a and b by regression analysis. If R^2 is low (<0.8) other models should also be tested. The biomass of the other trees in the plantation is then estimated from their diameters. For a small stand this may be done for every tree individually; for large populations the total biomass may be estimated using the mean diameter and the total number of stems in the stand.

Twelve is the absolute minimum number of trees per species that must be destructively sampled, but if a large sample is used it will give a more reliable model with closer confidence limits. Whatever the sample size chosen, it is essential that the sampled trees cover the whole size range of the population. The usual procedure is to use a stratified sample in which the trees are divided into size classes on the basis of diameter (or cross sectional area in the case of multi-stemmed trees), and sample trees are selected randomly within each size class.

For studies on a single site, the inclusion of tree height h in the regression function is found to contribute little to the goodness of fit of the model. However, a linear model of the form

$$W = a_i + b_i h \Sigma d^2$$

is more likely to be applicable across sites than one using diameters only, because height, unlike diameter, can be assumed to be independent of stocking level and silviculture treatment (Philip, 1983).

1.6 HERBACEOUS PLANTS AND SHORT DURATION CROPS

The required measurements are total biomass (t/ha = 0.001× kg/ha=0.01×g/m^2) and the contribution (%) of each species to that total. Total biomass is measured by harvesting, drying and weighing a number

of small sub samples, or quadrats. Quadrat size depends on plants spacing; 0.5 m×0.5 m is a convenient size for most grasslands; 1 m ×1 m may be appropriate for crops such as maize. Sample number (n) should be sufficient to reduce the standard error to about 10% of the mean. 20-30 samples per treatment distributed amongst replicates is usually sufficient. Sample location should best be random, but systematic with a random start is acceptable.

Procedure

1. Cut all herbaceous vegetation within the quadrat at 2 cm above the ground (to avoid soil contamination), and sort into live (green) biomass and standing dead if possible.
2. Collect the litter from the ground for an estimate of litter standing crop.
3. Dry all samples as soon as possible to prevent decomposition.

Species composition in mixed communities is estimated by the dry-weight-ranking technique. The technique is based on a multiple regression for the dry weight of a mixed sample of herbage of the weights of the three heaviest species in the mixture. Experience indicates that it is easier to assess visually the rank order of the species in quadrat than to estimate accurately their biomass. Tests in a large number of different communities have shown that the regression coefficients are fairly consistent between communities, and therefore do not need to be recalculated each time. The technique does not work well in communities completely dominated by one species, and tends to ignore rate species. The modified form given here, where the total biomass within the quadrat is also given a visual score, gives better results in communities where the total biomass is patchily distributed. Quadrat size should be small enough that the species ranking is simple, but large enough that most quadrats have at least three species in them. Quadrats 0.5×0.5 m square are usually adequate in grasslands. About 50 quadrats should be assessed per treatment.

Procedure

1. Walk around the plot to obtain a clear visual impression of what the minimum (1) and maximum (5) quadrat biomass looks like.

2. Locate the quadrat randomly or systematically after a random start.
3. In each quadrat (i) give the total biomass a score (W_i) between 1 and 5 according to whether it is near the minimum or maximum for the plot.
4. In each quadrat, give the species (j), which contributes most to the total quadrat biomass a rank score (r_{ij}) of 1, the second heaviest species a rank of 2, and the third heaviest species a score of 3. If a single species contributes more than about 70% of the biomass, give it ranks 1 and 3, or 1 and 2 (or even 1, 2 and 3 if it is the only species in the quadrat). Similarly the second species could get a 2 and 3 if necessary.
5. When all the quadrats have been scored and ranked, calculate the score for each species:

Calculation

Species j score = $70.2f\Sigma W_i + 21.1r\Sigma W_i + 8.7r \Sigma W_i$

where, ΣW_i is the sum of the quadrat scores for the quadrats where species j obtains rank r.

Add up the species scores to give a total score.

Determine the % contribution by species j to the total biomass:

Species j contribution to biomass (%) =(species score/total score) ×100.

1.7 EXAMPLE - I: COMPARATIVE ASSESSMENT OF METHODS FOR ESTIMATING BIOMASS IN FOREST ECOSYSTEM

1.7.1 Introduction

There has been a marked increase in the number of studies on forest biomass during the past decades with the realization that total organic production is important instead of considering the forest production system for stem wood. This is probably due to increase in pressure placed on our forests by the community such as demands for forest products, search for renewable source of raw materials etc. In addition to the productive role, the growing concern of well being of forest ecosystems has resulted in the appearance of numerous publications on forest biomass throughout the world (Parade, 1980) including India

(Singh and Sharma, 1976; Sharma 1971; George, 1977; Negi, 1984). These studies are utilized by some researchers with a geographical stand point, relating the distribution of productivity over land surface to either climatic factor (Paterson, 1956; Leith, 1972), or the distribution of main plant community (Rodin and Bezilevich, 1956). Such studies give us a general idea of productivity over the earth while neglecting the productive relationship in any particular forest stand. On the other hand some researchers are concentrating on the pattern and processes of production within a given forest stand as a base for understanding the energy flow and circulation of nutrients in the forest ecosystem (Satoo and Madgwick, 1982). Thus, biomass studies are essential for estimating Net Primary Production (NPP), understanding nutrient cycling and energy transfer and predicting the effects of tree utilization management procedures or other disturbances on productivity and stability of forest stand.

The oil crisis of 1970s has led a number of investigators to study the productivity of forests as a source of energy and chemical feed stock (Satoo and Madgwick, 1982). In India the man-made forests under Short Rotation Forestry (SRF), Social Forestry (SF), Energy Plantation (EP) and Farm Forestry (FF) program are of vital importance as these plantations indirectly help to relieve the tremendous pressure on the managed forest. However, it is essential to understand the potential nutrient drain from these forests under the wide range of harvesting practices including conventional clear-cutting.

For biomass estimation two distinctly separate situations can be considered. On one hand there is a typical research situation in which samples of trees and subordinate vegetation can be weighed in the field. While on the other hand the stand biomass can be estimated by prediction equations based on sampling over a wide geographical area. In this chapter, various methods of biomass estimation have been discussed and some comparisons have also been made between the results obtained by using different methods in a pure Sal forest (tropical moist deciduous forest) of East Dehra Dun Forest Division. The details of the stand are presented in Table 1.1.

Table 1.1

Details of the Stand

1. Area of the sample plot (ha)				0.10
2. Age (years)				47
3. No. of trees on the plot				80
(i)	Category	A	16	
(ii)	Category	B	21	
(iii)	Category	C	17	
(iv)	Category	D	14	
(v)	Category	E	12	
4. No. of trees/ha				800
(i)	Category	A	160	
(ii)	Category	B	210	
(iii)	Category	C	170	
(iv)	Category	D	140	
(v)	Category	E	120	
5. Mean diameter of the crop (m)				20.0
(i)	Category	A	10.5	
(ii)	Category	B	15.0	
(iii)	Category	C	20.4	
(iv)	Category	D	24.4	
(v)	Category	E	28.9	
6. Mean height of the crop (m)				19.6
(i)	Category	A	10.6	
(ii)	Category	B	15.2	
(iii)	Category	C	19.8	
(iv)	Category	D	22.2	
(v)	Category	E	23.8	
7. Basal area (m^2)/ha				25.2

1.7.2 Methodology

Selection of a sample plot: Generally it is not possible to measure all the trees of the forest stand, and hence the sample plots are taken to represent the forest. As such there is no firm basis for deciding on a suitable plot size but the smallest size of a rectangular plot should be

large than the height of the dominant tree (Satoo and Madgwick, 1982). However, it will be possible to select a suitable plot size by trial and error method using some easily measurable stand parameter such as basal area (Freeze, 1961). The effect of plot size on variability of estimated weight is illustrated in Table 1.2 using data from a natural stand of Shorea robusta. All biomass components were more variable than conventional mensurational parameters of basal area, diameter (DBH) and height. It clearly indicates that at least larger or more plots should be used for the estimation of biomass,. Similar results were also observed in a stand of naturally regenerated *Pinus virginiana* (Satoo and Madgwick, 1982). Increasing the plot size will reduce the variation substantially (Table1.2). Plantation would be expected to be less variable than naturally regenerated stands. Newbould (1967) suggested that sample plots in uneven aged mixed forests should be not less than 0.5 ha while in tropical rain forest the area must be 1/5 of the forest stand.

A perusal of Table 1.2 indicates that the stand biomass is substantially affected by the plot size less than 200 m^2. Considering the total stand biomass the size of the plot should be around 1000 m^2, preferably a square plot of 30 m × 30 m since the variation in stand biomass becomes negligible. The reliability of the estimates depends on the sample trees felled; therefore, the judicious selection of sample trees is a first requirement. Forked-and abnormal trees should be avoided and the trees on the edge of the forest should not be included.

Table 1.2

Variability of stand parameters as affected by plot size in natural stand of *Shorea robusta*

Growth Parameter	Plot size			
	100 m^2	200 m^2	400 m^2	1000 m^2
1	2	3	4	5
No. of trees	7	16	31	80
Basal area (m^2)	0.2015	0.476	1.163	2.5188
	(20.15)	(23.8)	(29.075)	(25.2)

Contd...

...Contd.

1	2	3	4	5
Average DBH (cm)	19.0	19.5	21.9	20.0
Average height (m)	18.9	19.2	20.2	19.6
Biomass (kg)				
Foliage	42.31	122.54	242.99	600.95
Twig + Branch	164.37	530.40	1013.41	2457.23
Bark	219.59	550.54	1120.15	2959.79
Bole	819.19	2020.42	4290.35	10786.88
Total	1245.46	3223.90	6666.90	16804.85
Biomass (t/ha)	125.00	161.00	167.00	168.00

1.7.3 Sample tree parameters

There is always a high correlation between DBH, height and weight. Thus it becomes essential to measure the DBH of all trees in a sample plot and height of some of trees. For weight determination, the sample trees can be selected either from the plot or outside the sample plot. Regression of height and diameter can be used to estimate the height of the remaining trees; a free hand curve may also serve the purpose. For example from the height and diameter curve obtained from 21 sample trees, the following regression equation has been worked out.

$$Y = 4.8980 + 0.6832 \text{ x } (r = 0.953) \quad ...(1)$$

Y = Height (m) x = DBH (cm)

1.7.4 Selection of sample trees

Sample trees should be of good form avoiding forked or damaged tree. One should also keep in mind that the number of the sample trees for measurement is limited by manpower available. Tree weight is usually closely related to the size, increasing proportionally to diameter raised to the power between 2 and 3 (Satoo and Madgwick, 1982). Stratified sampling based on DBH can reduce the number of the sample trees; however to get a valid regression model, it will be more useful if there is a fair distribution of sample trees covering the entire range of diameter on the plot. We should also avoid the trees growing on the edge on the forest.

1.7.5 Measurement of sample tree

Sample trees should be measured before felling in an identical way to those trees within sample plot for which weights are to be estimated. These trees are selected within or outside the sample plot depending upon the availability. In case of present study 19 trees of different diameters were harvested from the stand located in a pure Sal forest (tropical moist deciduous forest) of East Dehra Dun forest division. To develop good regression model 18 more trees were harvested from different localities. Thus a total of 37 trees distributed over the entire diameter range from 9.1 cm to 37.1 cm were harvested.

All the tree components viz., foliage, twig (2 cm), branch (2 cm) and bole were separated immediately and their fresh weight recorded in the field. A representative sample of each tree component (100 g for foliage twig and branch) was also taken for its oven dry weight estimation (80 ^{o}C). The bole portion of sample trees was cut into 2 m or 1 m long sections for the convenience of weighing. A 5 cm wide disc was also removed from the base of each billet for the estimation of fresh and oven dry weights of bark and wood (under bark) and also for the estimation of volume (over bark and under bark) of the main bole (up to a diameter limit of 5 cm over bark).

There is a marked variation in the heights of sample trees. As the diameters of the trees increase, there is a corresponding increase in the heights also for a particular site. Thus the site effect becomes conspicuous and is reflected in better height growth for the good sites, which in turn depends on the stand density also.

1.7.6 Estimation of stand weight for sample trees

As suggested by Satoo and Madgwick (1982) the following steps are involved in estimating the stand weight:

(i) Selection of sample plot.

(ii) Measurement of limited number of dimension on all standing trees in the plot.

(iii) In the case of research plots of selection, detailed measurements of sample trees.

(iv) Application of values for sample trees to the remaining unit area.

There are several general categories of methods used to estimate the stand weight from sample tree data.

1.7.7 Mean tree technique

The method is based on the detailed measurement of one or more trees of mean dimensions. Sample tree data are converted to a land area basis by multiplying the biomass of different components by the total number of trees per unit area. The average biomass in different components of three mean trees is used to get the biomass on unit area basis.

1.7.8 Stratified tree technique

This method is almost similar to the mean tree technique. Different diameter classes stratify the stand. One or more trees are harvested from each diameter class having parameters close to the mean of the class and the biomass figures of different components of each stratum are added up to get the biomass on unit area basis.

1.7.9 Unit area method

This method involves the harvesting of all the trees standing on a randomly selected plot. Depending upon the size, age, diversity, availability of manpower etc., this method is too much time consuming and calls for much hard labour and therefore, seldom used in biomass studies.

1.7.10 Basal area proportion method

In this method a tree of mean basal area is harvested and the weight multiplied by the number of trees per unit area; this gives the biomass. When a tree of mean basal area is not available, several trees closest to the mean basal area are sampled and the following formula is used for biomass estimation

$$W = \Sigma_w \frac{G}{g}$$

where W is the weight of trees of the plot, w is the sum of the weight of sample trees, G the sum of basal area of the plot and g the sum of basal area of the sample trees. A better estimate may be obtained when stratification is made with the diameter and taking trees of mean basal area of each stratum (Satoo and Madgwick 1982).

1.7.11 Regression estimation technique

This method is also called "dimension analysis of woody plot"

(Whittaker. 1961) and "allometry" (Kira and Shidei, 1967). This technique involves three steps as discussed below:

(1) Trees are tallied by species and diameter at breast height,

(2) The weights of the sample trees are related to easily measured parameters (DBH, heights etc.),

(3) Application of regression obtained in step (2) to step (1).

The regression equations for biomass prediction of different tree components have been obtained from 35 sample trees, which are given in Table 1.3 (Negi, 1984).

Table 1.3 Correlation coefficients (r) and prediction equations for different tree components as well as total biomass in *Shorea robusta* (Negi, 1984)

Dependent Variables Y	Log DBH (x)		Log D^2H (x)	
	Regression equations	**r**	**Regression equations**	**r**
Foliage	log y= -2.28061+ 2.33526 log x	0.944	log y= -2.52895 + 0.84866 log x	0.935
Twig	log y= -2.26097+ 2.23036 log x	0.930	log y= -2.48657+ 0.80640 log x	0.920
Branch	log y= -2.42358+ +2.86678 log x	0.936	log y= -2.67889+ 1.02741 log x	0.16
Bark	log y= -1.40374+ 2.25082 log x	0.954	log y= -1.78422+ 0.85390 log x	0.991
Bole	log y= -1.95385+ 3.10398 log x	0.986	log y= -2.34087+ 1.14144 log x	0.993
Total	N.D.		log y= -1.78825 +1.04848 log x	0.994
Root	log y= -1.72010+ 2.65696 log x	0.977	log y= -1.88750 +0.93460 log x	0.981
Total	N.D.		log y= -1.54325+ 0.93460 log x	0.995

N.D. = Not determined

Table 1.4 Comparison of biomass (t/ha) estimates obtained by using various methods in *Shorea robusta* stand

Components	Mean tree Technique	Stratified technique	Basal area proportion Method	Regression method	
				Log D^2H	Log D
Foliage	5.3	5.7	4.5	4.8	4.7
Twig+Branch	15.5	23.5	20.1	22.1	21.6
Bark	27.6	27.2	24.7	47.7	27.4
Bole	107.6	109.6	104.0	112.0	112.3
Total	156.0	166.0	153.3	166.6	166.0

Out of the five methods used, the mean tree technique and the basal area proportion method gave six to eight per cent under estimates of the total biomass of 166 t/ha estimated by stratified tree technique. Results from the test plots reported by Satoo and Madgwick (1982) indicate that the mean tree method can give under estimates of canopy weights; however, estimates based on several trees closest to mean basal area generally gave results within ten per cent of actual plot values. The frequency distribution of diameter classes may not necessarily be symmetrical about the mean and the asymmetrical distribution may result in the under estimates or over estimates of the biomass. In the present case, the best results have been obtained by regression methods after the stratified tree technique. Since there is a good correlation between the tree weight and the linear size (DBH, height etc.) the regression techniques are most widely used and the only methods for estimating biomass of the stand where no direct sampling has been undertaken though the component weights particularly the leaf is subject to large variation (Satoo and Madgwick, 1982). In our discussion the regression estimates of foliage weight as compared to that of stratified technique are about 16 per cent under—estimations while the (twig + branch) estimates are within 6 to 8 per cent. The stratified tree technique gives good and reliable estimates if sufficient numbers of trees are included in each stratum; the regression technique is the next choice where destructive samplings are not possible.

The stratified tree technique is undoubtedly the best method but it is time consuming and expensive; therefore, there is a need to develop

estimating equations of wide applicability so that reliable estimates of stand biomass may be obtained without recourse to the laborious destructive sampling.

A comparison of biomass estimated by using various methods has been made in Table 1.4.

1.8 EXAMPLE - 2: Overview of Methodology for Teak Biomass and Nutrients Study (within each climatic zone)

1. Select 5 plantations to cover wide range of ages, trying to keep climatic and soil factors constant. This is a chronosequence.
2. For each plantation, randomly locate and layout about 20 plots, attempting to ensure that they cover the range of site within the plantation. Plots should contain a minimum of 12 trees - it is important to be as small as 10 × 10 m.
3. Measure the girth at breast height of all trees, and record these and other site details on the standard form.
4. Calculate the basal area (BA) and stocking per ha.
5. Group the 20 plots into 5 groups on the basis of BA (perhaps taking into consideration stocking or mean girth).
6. Select the mean plot from each of five groups - these will be sample plots to be used for the measurement of the biomass trees.
7. Take soil samples from each of the 20 plots, using the depths 0-20, 20-50 and 50-90-cm. Label samples with plot number and soil depth. Analyze using the standard methods.
8. Rooting depth has to be estimated for each of the 20 plots.
9. Soil description should come from one or more pedons which represent the soils in the compartment.
10. Bulk density for the three depths used for the above sample analysis needs to be measured also. Bulk density for the 0-20 cm is likely to be more variable but more critical, so for this horizon it should be measured in each of the sample plots as well as at the pedons.
11. Biomass of one tree of about average girth from each of the 5 selected sample plots. This tree should be typical of the plot

and not grossly malformed.

12. Follow the standard destructive biomass procedure and enter the data on the field form provided.
13. Enter the data on the spreadsheet developed for this study, backing up the data on computer floppies (at least two backups).
14. Use the modified basal area ratio method to calculate the per hectare values for each of the 20 plots.
15. The data set for subsequent analysis will be:

    For the matrix of 5 plantation ages and 20 plots per compartment, there will be biomass by tree components, nutrients by tree components; soil nutrients by various depths, rooting depth, tree volumes, basal area and stocking.
16. Data analysis could employ the following techniques:

    Analyses of covariance to see if there are significant stand age differences.

    Covariate could include a composite soil/site factor.

    Correlation techniques.

    Regression models.

    Other multivariate techniques.

    Graphical methods.

    Balance sheet approach.

    Effect of harvesting practices on nutrients.

1.8.1 Site description sheet for biomass studies in teak plantations

Plantation number	:	Planting Year	:
Sampling Date	:	Age (Years)	:
Division	:	Range:Compartment	:
Stocking (stems/ha)	:		
Soil type	:		
Topography	:		

1.8.2 Sample plot data sheet for biomass studies in teak plantation

Plantation Number : Plot Number :

Plot size: m= m^2

Aspect Slope(degrees): Topo.position*:

* Top, Mid, Lower or bottom

1		12		23		34	
2		13		24		35	
3		14		24		36	
4		15		26		37	
5		16		27		38	
6		17		28		39	
7		18		29		40	
8		19		30		41	
9		20		31		42	
10		21		32		43	
11		22		33		44	

Record all girths to nearest mm. eg 24.4 cm; correct plot areas for slope.

Summary :

Stems/ha :

BA/ha. (m^2) :

Mean girth (cm) :

Soil Sample collected? : Y/N

Signature:

1.8.3 Teak biomass sampling procedure

The introduction of the new standard forms and then entry onto the spreadsheet should lead to fewer errors and higher quality data. The system has been designed for ease of use.

Field procedure

1. Before felling the tree, measure crown width (2 diameters), girth at stump, BH and on large trees or fluted trees, the girth at about 0.6 -0.7 m. Record these to nearest mm, and mark breast height point.
2. Fell tree, preferably onto a sheet.
3. Lay tape along the tree using the BH mark (1.37m) as a reference point. Enter the height at which the stump was measured and the stump disk is to be taken.
4. Measure height to first branch and total tree height (all heights to be recorded to nearest 0.1 m).
5. Decide on how many growth measurements and stem sample discs need to be taken for good representation of the stem. The form allows up to four discs to be taken. Discs should be taken at approximately equal distances along the trunk. There will always be at least two discs (stump and top disc). Mark these points on the stem, recording their heights.
6. Cut the stem and weigh the logs, recording to the nearest kg.
7. Immediately cut the sample discs (uniformly 5 cm thick) before drying can occur and quickly weigh these (with bark) to nearest g. Label the discs with the sample number; record measurements and label number.
8. Where a disc is taken, girth, bark-thickness and sapwood thickness should be recorded (nearest mm), taking the mean of 4 measurements.
9. Complete the menstruation data on the stem by measuring additional girths and bark thickness, as may be required.
10. Note: volumes OB and UB of the stem will be calculated by Smailian's formula, which require the girth at each end of the log and the log length (and the bark thickness to get UB volumes).
11. Branch wood (>20cm girth) should be weighed green, length measured to nearest 0.1m and the single mid-point girth taken. Record each branch wood separately on the form. (Calculations use Huber's formula for branch wood OB volumes).

12. Quickly sample by taking a series of 2-cm thick discs (say 2 or 3 from each branch wood) from these branches, covering the range of diameters. Combine together into a single sample; quickly weigh to nearest g, label and record weight and label number.
13. Do not attempt to take a uniform 100 g sample.
14. Follow a similar procedure for branches, twigs and leaves, combining many small randomly chosen pieces to make a sample.
15. For branches, twigs and leaves, total fresh weight is recorded.
16. Remove the roots and divide into the stump and central core region (say down to 20 cm girth) and into coarse lateral or sinker roots (> 2 mm). Weigh and record these two separately.
17. The stump portion is not sampled but the stump disc taken at the bottom of the log is assumed to represent it. Coarse roots are sampled, by taking several pieces at random to represent all sizes.
18. Before leaving the tree check that all data have been recorded as required, and that all samples are clearly labeled and are being taken to the laboratory.

1.8.4 Laboratory procedure

At the laboratory there will be separate forms that will have dry weights and nutrient analysis recorded on them. The following points should be noted:

1. Labeling should be clear and will have been recorded on the field form if there is any query. Check that all samples are present.
2. Stem discs will have to be divided into wood and bark (green weights of each not required) and need to have further labeling (e.g. a W or B added to the number).
3. After drying all samples at 65-70°C until there is no further reduction in weight, weigh and record to the nearest g (nearest 5 or 10 g is not good enough). There are sheets for recording these.

4. Finely grind and analyse for N, P, K, Ca, Mg, and Na concentrations; record on appropriate sheet.
5. Enter all data from the field and laboratory sheets into EXCEL using TEAKCAL.XLS spreadsheet. This will do all the calculations. Check that data.
6. Place a hard copy of the summarized data on file.

1.8.5 Measurements

	Units	Measure and record to nearest
Crown diameter	m	0.1m
Heights	m	0.1m
Girths	cm	mm
Bark thickness	mm	mm
Sapwood depth	mm	mm
Fresh weights	kg	kg (or within 3 %)
Sample weights	g	g
Nutrients	%	varies

1.8.6 Sample tree field data sheet for biomass study of teak

Plantation number: Date sampled:

Plot number: Tree number:

Crown diameters (m) 1. 2.

STEM

	Height m nearest 0.1	Girth cm	Bark thickness mm	Sapwood thickness mm	Total FW kg	Sample FW G	Sample No:
Stump	0.						
	0.						
B.H.	1.37						
Top							

Notes: There must be at least two discs (stump and top) taken; others may be taken if dealing with large tree. Enter the total fresh weight of each section before cutting the disc. For accurate volumes additional girth and bark thickness (mean of 4) measurements are required: at about 0.7m and at BH, and at about 2-3 m intervals above breast height on trees with long boles. The average sapwood thickness (mean of 4 and excluding bark) is required for each disc.

Height first branch (m):

Total tree height (m):

FOLIAGE

Total Foliage F W (kg):

Sample F W (g): Sample no:

BRANCHES

Branch wood				**Branches**			**Twigs**
Length M	Girth cm	F W Kg	F W Sample G	F W Kg	F W Sample G	FW Kg	F W Sample G
			Sample No		Sample No		Sample No

Notes: - Branches are divided into three categories :> 20 cm girth; 5-20 cm and twig (<5cm). Large branches are freshly weighed separately (to nearest 0.1 kg); other branches or twigs may be weighed together. Sub samples are required from each category and should be weighed green in the field to the nearest g. Branch bark need not be separated from branch wood. For the branches >20 cm their girth at the mid point along the branch and length is required to obtain branch volume (Huber's formula)..

ROOTS

Stump F W (kg):

Coarse root (kg):

Sample Coarse root FW (g): Sample no:

CHECK LIST

All field measurements entered Y/N

Number of samples? .....

Samples clearly labeled? Y/N

Measured and recorded by: .....

1. 8.7 Biomass sample sheet for recording dry weights

Plantation no:

Plot No:

Tree No:

Stem samples

Field Sample no.	Fresh Wt.g	Wood dry wt.g	Bark dry wt.g

Note: The wood and bark sample numbers will need to be given either a/W or a/B to distinguish them apart once they have been separated and prior to analysis.

Other Sample

Sample no.	Type	Fresh wt. g	Dry wt. g
	Foliage		
	Branch wood		
	Branch		
	Twigs		
	Coarse roots		

Dry the samples until they reach a constant weight and record the values in the table. The fresh weights are recorded here again for checking purpose.

Date: Recorded by:

□□□

2

NUTRIENT CYCLING

2.1 INTRODUCTION

The interchange of chemical elements between living organisms and the physical and biological components of forest ecosystem may form an extremely complicated system, essentially cyclic in nature and may broadly follow the organic system (Ovington, 1962). In order to understand the magnitude and-pattern of circulation of the chemical elements, which may be characteristic of an individual element, the cycling rate and standing state will have to be quantified. Nutrient cycling may be a good indicator of the continuity and stability of any living system and may be believed to be a useful strategy for ecosystem analysis (George, 1977).

The forest and the soil together constitute a system, in which both work complementary to each other. The basic mineral nutrients to the forest crop are provided by the soil due to weathering of rocks and minerals. The soil is recharged with the mineral nutrients after the decomposition of the organic matter obtained from trees due to leaf fall, etc., the nutrient cycle in forest means movement of basic nutrients from atmosphere to soil and soil to the atmosphere. Several factors such as water, micro organisms, condition of decomposition of organic matter

etc., affect these cycles.

In a forest ecosystem, two major pathways of flux can be recognized namely:

(1) Bio-geo chemical (open) cycle.

(2) Biological (closed) cycle

The bio-geo-chemical consists of a nutrient reservoir pool, which is large and there is exchange pool which is small but active. The biochemical cycles involve gaseous nutrient cycle, where atmosphere is reservoir pool and sedimentary nutrient cycle, where earth crust is reservoir pool. These cycles involve input and output of mineral elements. The inputs of nutrients include:

(i) Addition of nutrients by precipitation
(ii) Weathering of parent rocks
(iii) Nitrogen input through nitrogen fixation by micro organisms, and electric discharges in thunder storms.

Precipitation is one of the most natural means by which nutrients are added to the forest ecosystem. It is reported that the annual nutrient supply through rain water in temperate regions are less compared with tropical regions.

Supply of nutrients is also made in soil by weathering of soil particles and parent material. This is a part of sedimentary cycle. Weathering of soil particles increases nutrient availability and weathering of rocks increases nutrient capital in the soil. The rate of weathering is high in forest soils, because of better weathering environment. Nitrogen is added in soils by symbiotic and free living micro organisms. The net annual gain of nitrogen may be about 50kg to 500kg per ha in tropical forests. Forest canopies also trap air-borne materials.

The main sources of output are loss of nutrients through harvesting of trees, grazing, leaching, fires etc. The biological cycle may involve a cyclic circulation of nutrients between the forest soil and the biotic communities and may include the processes of mineral uptake (or) absorption, retention (in the annual accumulation of biomass) and restitution (or) losses (leaf litter, organic debris, washing by rain etc) (Duvigneaud et al., 1970). This may be expressed as below:

Nutrient uptake = Nutrient retention + Nutrient returned

In this chapter, the methodologies for investigating the nutrient cycling in forest and plantation ecosystem are described. To study the nutrient cycling, nutrient retained and nutrient returned should be calculated.

2.2 NUTRIENT RETAINED

The nutrient retained in the annual biomass production of forest vegetation may be obtained by multiplying the biomass components with their respective nutrient concentration. The nutrient contents of the standing crop may differ substantially between various forest types according to the degree of uptake and crop biomass, which may in turn depend on tree age and site quality, even within the same species. The increase in nutrient contents of the standing crop with stand age observed in plantation and forest stand should have a direct relationship to the total biomass (Rodin and Bazilevich 1967). As such, the nutrients accumulated in various tree components may vary considerably.

2.3 NUTRIENT RETURN

Estimation of litter production and its nutrient content per unit area needs to be studied to investigate the nutrient return in an ecosystem. Besides nutrient in litter fall, the forest floor also receives them from through fall, stem flow and canopy interception.

2.4 METHODOLOGY TO STUDY NUTRIENT CYCLING

2.4.1 Litter estimation

Litter is conveniently divided into two components, fine and coarse litter. Fine litter is mainly leaves but also includes flowers, fruits and fine twigs. It is relatively easy to set a system of traps, for example fine nylon-mesh trays, and to obtain a statistically satisfactory record of fine litter fall over a year (or two) of study.

Coarse litter, which is branches, limbs and falling tree trunks, is very heterogeneous in both space and time and it is much more difficult to get a meaningful record, although in amount coarse litter may exceed fine litter.

2.4.2 Litter trap construction

Litter traps are bags or boxes supported just clear of the ground

with an aperture of 0.25-1 m^2. A circular construction is best as it minimizes edge effects. Woven plastic bags are light weight for use in remote sites and can be tensioned into shape using lines attached to D-rings sewen around the mouth of the bag. The traps must allow free drainage of rainwater but have a mesh size of approximately 1 mm or less to retain fine litter fractions. Trays on the ground surface can be used to measure litter-fall from dwarf shrubs etc.; but animal activity, drainage and wind can present problems.

Similar considerations apply to collections of litter from quadrats on the ground, which may be necessary for estimating falls of palm fronds and large woody litter. Trash fractions, which often have low mass but high nutrient content, however, will be lost by this method.

Procedure

1. Randomly locate litter traps (for material other than branches) within moderately homogeneous plots, or in a stratified random pattern (with 10 traps per subplot) in sites where it is necessary to include major variation in topography, soils and vegetation structure.

Note: To achieve a 5% standard error about the mean, Newbould (1967) recommends the use of a minimum 20 traps/plot. In very heterogeneous sites, however, higher numbers of traps may be required.

2. Collect litter every 2 weeks and air-dry it. More frequent collections may be necessary for litters, which decompose rapidly, e.g. some tree legumes and while less frequent collections may be made under dry conditions (though the possibility of the litter becomes contaminated with dust and or animal faeces should be recognized).

3. Sort the dried material into:

a. Leaves (including petioles and folinr rachis);

b. Small woody litter (twigs < 2 cm in diameter and bark);

c. Reproductive structures (flowers and fruits could be differentiated);

d. Trash (sieve fraction < 5 mm).

(For palm fronds, the leaflets, the rachis below 2 cm, and the remaining parts of the rachis should be weighed and recorded separately).

4. Oven-dry sub samples of litter to obtain correction factors for moisture content

5. Express all fractions defined above on dry basis in g/m^2/year or t/ha/year with 95% confidence limits.

6. Estimate branch fall from large (e.g. 100 m^2) ground quadrats. Break twigs at the 2 cm diameter point, weigh the > 2 cm diameter material, sub sample for oven-dry mass and other determinations as required.

2.4.3 Herbaceous litter and above-ground crop residues

The minimum level of sampling is at maximum and minimum biomass associated with major seasonal changes or perturbations; i.e. sampling four times a year under climatic regimes with strongly bimodal pattern of rainfall. This will underestimate litter inputs as a consequence material turning over between sampling dates and sampling at regular intervals every few weeks is recommended.

Procedure

Determine herbaceous litter (including grasses and forest ground flora) by harvesting quadrats in conjunction with biomass estimates.

Separate litter, where possible, by plant species for the most frequent 80% of species and bulked for the remaining 20% (This may be impractical in species-rich communities).

Determine crop residues after harvest and at the time of ploughing or other manipulation.

Oven-dry litter sub samples to obtain correction factors for moisture content. Litter heavily contaminated by soil may need to be corrected for 'ash' content as well.

Express all fractions defined above on an oven dry basis in g/m^2/year or t/ha/year with 95% confidence limits.

2.4.4 Other inputs

Mulches, manures and fertilizer

Information on the type of input applied, the amount applied, and the date of application is necessary. For example, information required for mulches would include the type of mulch (e.g. rice straw), the amount applied on a dry weight basis (t/ha), and the application date(s). A representative sub sample can be taken for nutrient and other analysis. Details on methods of incorporation (e.g. surface application, ploughed

to a certain depth, banded) of each of the inputs should also be noted. Similar information is necessary for manure application.

For fertilizers, specify the material applied (e.g. urea, single super phosphate), quantity applied and application date (s).

2.4.5 Herbivory

Record the dates of commencement and termination of feeding, the type of herbivore (species, browser, grazer, etc.), and the number of animals in the plot and estimates of their individual masses. These data will permit the stocking level (kg/ha) to be calculated, given the plot area, and the rates of plant consumption, defecation and urination (kg/ha/day) to be estimated.

2.5 LITTER DECOMPOSITION AND NUTRIENT RELEASE

Decomposition is a complex process regulated by the interactions between organism (fauna and micro organisms), physical environmental factors (particularly temperature and moisture) and resource quality (lignin, nitrogen and condensed and soluble polyphenol concentrations) (Swift et al., 1979). As decomposition progresses, soluble and particulate materials from the litter, organism tissues and products of microbial metabolism are separated from the original resource by leaching, physical fragmentation and animal feeding activities. These products are then transported by wind, water and gravity to soil microhabitats, which have a different set of conditions regulating decomposition to those of the parent material. An almost intractable problem in quantifying litter decomposition is the need to impose methods, which enable the experimental material to be identified without affecting the variable, which regulate the component processes.

2.5.1 Litter bags and decomposition rate constants

Enclosing litter in a mesh bag makes it possible to recover the residual experimental material and defines the conditions under which the organisms operate. However, the mesh bag and compaction of the litter can create different microclimates to condition in unconfined litter and the incorporation of material into soil is also affected. Nonetheless the standard litter bag remains one of the most convenient methods for comparative measurements of decomposition between sites and treatments.

The minimum requirement for litter decomposition rates in these studies is the time for 50% loss of the initial mass (t_{50}) but most studies in the literature report the decomposition rate constant "k" from the negative exponential function:

$$W_t / W_o = W_o e^{-kt}$$

Where W_t is the amount of the initial mass (W_o) remaining at time "t".

This is more conveniently expressed as the regression function:

$$Log_n (W_t / W_o) = log_n W_o - kt$$

The use of the single exponential model assumes that decomposition rates are constant over time. In fact, litter mass losses often show a fast initial phase due to leaching of water-soluble material (which is largely an experimental artifact of drying and re-wetting the litter), a slower second phase dominated by the decomposition of cell wall constituents such as hemicelluloses and cellulose, and a slow phase regulated by lignin and microbial products. This series of curves can be described by fitting a two - (or) three - phase exponential model with a rate constant for each of the fractions (Wieder and Lang, 1982).

2.5.2 Decomposition of unconfined litter and turnover rates

Measurements of mass losses from unconfined litter under natural conditions are only possible in the initial phases of decomposition before the material starts to disintegrate. The method is most satisfactory for wood and other discrete materials, which can be tagged or attached to a tether (Lang and Knight, 1979). For branches and tree boles changes in relative density (weight per unit volume) provide a useful measure of mass loss without sacrificing the whole unit. Extensive decomposition of wood often occurs before branches and tree boles fall to the ground. This can be determined by comparing the relative densities of standing dead and forest floor material with live wood but the age of the material is difficult to calibrate (Swift et al., 1979).

Litter decomposition rates on the soil surface can be estimated from changes in litter standing crops over intervals of time where (i) there is a pulsed input of material (such as crop residues at harvest), (ii) the material has decomposed before the next input, or (iii) age classes of material can be distinguished. In most natural systems it is often

difficult to distinguish litter cohorts; (e.g. grasses). Under these conditions determinations of litter turnover rates provides a useful basis for comparing litter dynamics in different habitats in relation to climate and site factors. The turnover coefficient "k" is calculated as the quotient of litter input (I) divided by the standing crop (S):

Even for small litter, the same fractions must be represented in the inputs and standing crops when calculating the quotient and this is usually only possible for leaf litter and small twigs (Anderson and Swift, 1982). Sites subject to fires (Woods and Raison, 1982) and heavier grazing present obvious difficulties in estimating litter turnover by input/standing crop determinations.

It is unfortunate that, for historical reason, the turnover-coefficient and decomposition-rate constant, which have no formal relationship, are both designated by the letter "k" and the use of this term must therefore be specified. $K = I/S$

2.5.3 Litter bag methods

Modified method

For studies in agricultural systems, where inputs of crop residues, green manures or dung have largely decomposed by the start of the following cropping season, an alternative procedure has been developed using bags as mesh cylinders to retain the experimental material in contact with the ground. The method is most appropriate for surface litter treatments; sampling and processing buried litter requires modification of the protocol depending on the material and soil texture.

The advantages of the method are that it reduces microclimatic artifacts, allows natural access by soil fauna, enables measurements to be made of litter incorporation into soil and sampling can also be combined with determinations of other soil properties and processes. The disadvantages are that the method involves disturbing the soil (hence is most appropriate for arable systems) and samples take longer to process. The method is also less suitable where litter fall occurs during the experimental period though this can be excluded by fine mesh covers (e.g. mosquito-net). The method is unsuitable where there is residual standing crop of litter.

Procedure

1. Open the bags to form mesh tubes (ca. 20 cm diameter by 30 cm deep) and bury them to about half of the depth in the soil. For stony or shallow soils the bag can be cut in half and only 5 cm inserted below ground. Placement is made easier by using a metal sleeve, which fits, inside the bag to hold the cylinder rigid during handling. In tilled soil, large stones may be removed from within the cylinder to facilitate subsequent sampling.

2. Locate the mesh cylinder on a random basis in the field and add a known mass of experimental material in parallel with plot treatments.

3. Sample 3 to 5 bags on a random basis at regular intervals. Collect as much of the litter from the soil surface as possible (this may include small stones and aggregates) and put into a bag.

4. *Surface-litter treatments:* Soil cores (ca. 5 cm diameter) can be taken after the removal of litter and divided into depth increments to determine moisture content, organic carbon distribution, soil organic matter fractions and N-mineralization rates in the laboratory. The remaining material can be dug out and hand sorted for roots and soil macro-fauna.

Buried-litter treatments: Take cores for associated measurements and then remove all the soil in the bag to a suitable location for processing.

5. Fill in the hole with soil from the margin of the plot and mark the location to avoid resampling.

6. *Surface-litter treatments:* In the laboratory sort the bagged litter material by hand, or shift in a coarse sieve, to separate the large litter fragments, stones and soil aggregates such as termite/earth worm worked material.

Place the residual litter and soil material in a bucket of water, briefly swirl to suspend litter fragments, and carefully decant through a 2mm mesh sieve. Experimental material retained on the sieve is classified as litter. Use a 0.25 mm sieve to further separate material in the washings if soil litter is to be determined.

Buried litter treatments: Hand-sort the material for litter (fauna and

roots) as far as practical. Sub sample the soil and separate by water floatation as described above. In soils with high clay content, sub samples may be deflocculated with a water softener to release occluded material.

7. Drain washed litter thoroughly before air-drying. Take sub samples for oven dry weight determinations.

Note: Little leaching occurs if washing is brief but this can be readily checked. It may be impractical to use distilled water for this separation but the water chemistry should be borne in mind in subsequent analysis. Litter which is heavily contaminated by clay material may be separated by more prolonged washing but effects on nutrient leaching must be assessed. Water softeners used in deflocculating may have high concentrations of phosphorus, so samples treated that way may not be suitable for nutrient analysis. In some cases, such as where termites have infilled woody materials with soil, it may be necessary to ash the experimental material and express results on an ash-free basis.

2.5.4 Data analysis

Plot the data for % initial mass, and $\log_n$ % initial mass, vs. time (days) to inspect for trends.

If the untransformed data show linear trends, estimates of t_{50} are made by calculating the regression and solving the equation for t = 50%.

The convention is to fit a single negative exponential function to derive the decomposition rate-constant "k" ; t_{50} can then be estimated from the reciprocal of k/day.

The rate-constant "k" is the slope of the regression of $\log_n$ % remaining vs. time. If time is in days then the slope is -$\log_n$ % day. To obtain k/year multiply by 365.

For example, for *Shorea affinis* (sampled over 294 days in a rainforest in Sri Lanka), k = -0.0036/day; k/year = 0.0036 x 365 = 1.22/ year (values for k are conventionally expressed as positive values). The estimate of t_{50} = 1/0.0036 = 278 days.

2.5.6 Decomposition standards

Birch (*Betula spp.*) lollipop sticks are used as decomposition standard for inter-site and regional comparisons using natural vegetation (where possible) and a derived site in each study area.

The sticks (100 × 10 × 1 mm) are secured in bundles of three

with a wire or plastic tie at each end of the bundle. Two sets of bundles are used to investigate the effects of litter and soil conditions on decompositions rates.

Procedure

A. Place one set horizontally on the soil surface and bury the other set upright in the soil with the tips at the soil surface. Pairs of bundles, one of each set, are placed and samples on a random basis.
B. Collect sample of 10 bundles of each set at intervals of 3 months.
C. Remove the middle stick from the bundle, dry at 85°C and weigh.

2.6 SOIL AND PLANT SAMPLING FOR LABORATORY ANALYSIS

Sampling and sample preparation is arguably the most important stage of any study; excellent laboratory analysis does not compensate for poorly collected, poorly prepared or unrepresentative sample. Wherever possible, label all sample containers prior to going to the field. Field-fresh soil samples are often moist; these should be collected in plastic bags or tubes rather than paper bags. Plant materials, on the other hand, should be collected in paper bags to reduce decomposition accelerated by a moist environment prior to preparation for analysis. Upon return to the laboratory, examine plant samples for contamination, e.g. dust or mud; a brief rinse with water may be required.

Unless the analysis requires a field moist sample, air-dry all samples as soon as possible to halt biological transformations.

2.6.1 Soil sampling

Auguring procedure

1. Remove surface plant and litter material from a minimum of 5 randomly selected auger sites.
2. At each site auger to a known depth (e.g. 30 cm) and put the auger contents in a clean plastic bucket so that all 5 auguring can be thoroughly mixed prior to sub sampling. Take a sub sample at about 500 g (one cupful). Discard the remaining soil.
3. Repeat step 2 for the next depth required for each auger hole.

Undisturbed cores procedure

1. Clean a flat surface (either a vertical face in a profile pit or a horizontal surface at any known depth).
2. Firmly drive a soil coring cylinder (of known volume and mass) fully into the face causing minimum disturbance and compaction to the core.
3. Cut away surrounding soil as to be able to cut neatly across the inserted end of the cylinder.
4. Carefully lift the core away, trim the ends flush with the cylinder ends, and cap tightly.

2.6.2 Plant sampling

The part of the plant that needs to be sampled and the sampling strategy depends on (i) the purpose for which the samples will be used (i.e. the types of analysis), and (ii) the type of plant to be sampled. No standard method is thus applicable. The general concept is taking several (minimum 5) sub samples, mixing them to make a composite sample and finally taking a sub sample for analysis.

2.7 SOIL, PLANT AND LITTER MATERIAL PREPARATION

2.7.1 Soil material

Note: As many of the variables of interest in ecological studies are biotic, or biologically medicated, several of the analysis must be conducted on field-fresh soil samples; the following guidelines relate to soils that do not need to be field-fresh.

Procedure

1. Air-dry the soil by spreading it out in a shallow tray in a well-ventilated place protected from rain and contamination. Alternatively soils can be dried in a forced air oven at a maximum temperature of 60°C. Break up any clay clods. When the soil is dusty it is dry enough.
2. Crush the soil lumps gently so that the gravel and roots etc. are separate from the mineral soil.
3. Sieve the soil through a 2 mm sieve leaving the gravel and roots etc. in the sieve.
4. Pick out the roots and save if required.
5. Retain the gravel for weighting if required. This should be done

if it appears to be about 5% or more by mass of the original sample.

6. Retain a representative sample (of the sieved soil approximately 250 g), by e.g. coning and quartering, for analysis.

Note: Coning and quartering is a simple and effective method of sub sampling loose, <2 mm material: mix, then pile the material in flat cone or mound. Divide into four quarters by cutting across the middle in an "X" shape with a blade. Discard two opposite segments, and mix and re-cone the other two. Repeat the process until sufficient material remains.

2.7.2 Plant material and litter

Procedure

1. Dry green material and litter at a maximum of 60°C; dung should be dried at a maximum of 40°C to prevent volatilization.
2. Grind all the material to pass a 0.15 mm mesh.
3. Retain a representative sample of approximately 10g, by e.g. coning and quartering, for analysis.

2.7.3 Sample storage

Both soil and plant material will satisfactorily store for long periods (i.e. > 1 year) if they have been correctly prepared. Samples are stored in clearly labeled, air-tight, termite-proof containers; the storage room should be well ventilated.

2.8 EXAMPLE: NUTRIENT CYCLING STUDY IN A TEAK PLANTATION : CONCEPT

The purpose of this example is to look at the major nutrient pools and cycles in a semi- mature teak stand, in order to better understand the ecology of these important plantations. It is envisaged that the timing and movement of nutrients will be related to seasonal climatic and growth patterns. However, it is unclear how closely these coincide or if there are major losses and gains to the system. It is important to clearly understand that the focus is an in-depth understanding of the stand ecology and that each of the various sections are interlinked.

2.8.1 Site

The site should be of easy access with an all-weather road. The

side should be flat or have a very gentle slope, and not subject to excessive overland water flow, pending of water or erosion. Soils should be typical of the region. A well stocked stand of 20-30 years old should be selected. There needs to be an open area nearby for collection of uncontaminated rain.

2.8.2 Plot layout

Some 10 temporary plots (with at least 12 trees) should be laid out in the compartment and their stocking, basal area (BA) and mean girth obtained. This information will be valuable when later (say 0.05 - 0.1 ha) permanent study plot should be established, containing at least 20 trees, as well as sufficient space for the various studies. The corners of the plot should be pegged and the plot fenced off against stray animals.

All trees in this plot should have their BA level marked, numbered and be measured for girth and total height at the start of the study, when the trees have lost all their leaves and at the end of the study (after 365 days).

The key measurements to be obtained over a one-year period are: Biomass and Nutrients in three occasions (to estimate internal cycle and nutrient accumulation patterns).

2.8.3 Biomass and nutrient patterns

At the start of the study five trees should be sampled for biomass and nutrients when the trees are in full leaf and well before leaf-fall to get samples of the maximum nutrients in the foliage and stand. The biomass relationships from these five trees may be used to predict the biomass and nutrient accumulations of three occasions; at the start of the study; when the trees have lost all their leaves and at the end of the study year. The girth and height measurements on all plot trees are critical for these estimates.

The five trees should be selected to cover the diameter range and should be normal looking (i.e. not malformed or excessively branched etc). The methods used should follow the standard procedure, taking particular care in getting representative samples of foliage, twigs, branches and branch wood. These trees must come from close to the permanent plot but not within it. Nutrient analysis will accompany the biomass study and will be appropriate to use for estimating nutrients at the beginning

and end of the study. However, representative branch wood, branch and twig samples need to be collected from five trees when the trees have lost their leaves, and analyzed for nutrient concentrations. The purpose of these samples is to estimate the internal nutrient cycle and the storage of nutrients in the crown. Nutrients are probably also stored in recently formed xylem, the cambium and phloem of the stem and roots; it would be a challenge to estimate these without felling the trees but could be done, if desired.

The modified basal area ratio method may be used to convert data to a per hectare basis.

2.8.4 Soil nutrient pools

This should be sampled on the three occasions when the measurement of the main study plot, described above, are made. The sampling scheme should follow the standard procedures used for the chronosequence study. However, in this case a measure of soil variability is needed so the samples should not be bulked in the same way. It is suggested that the plot be divided into 10 × 10 m squares and bulked samples be collected from each of these quadrats (5-10 cores/quadrate-standardize this).

Soil descriptions (pedon just outside the plot) plus bulk density are also required. Collect a 0-20 cm bulk density sample from each of the quadrates, plus deeper once from the pedon.

Statistical analysis will give estimates of the means and repeated ANOVA might also be a useful technique.

2.8.5 Litter fall

This will be sampled inside the plot. Some ten 1 × 1m randomly located subplots (quadrats) should be laid out. These subplots should be numbered so they can be sampled in the same order each time. The forest floor should be cleaned and covered with shade cloth (1.5 × 1.5 m and pegged to the ground) to reduce soil splash. A portable sampling frame of 1 × 1 m should be made. At the time of sampling this should be laid over the litter and material within it carefully collected. Other litter on the outer part of the cloth should be swept aside.

Label samples and bring to the laboratory where the individual dry weights can be obtained. Each sample should be divided into three

components; teak leaves, teak reproductive parts and other material (bark, branches, other litter etc). Quadrats 1-5 and 5-10 may be bulked to give a total of six samples for chemical analysis per sampling period.

Normally sampling should be at monthly intervals, but extra could be justified at the time of peak litter fall, particularly if rain is likely. The study should continue for a full year.

Statistical analysis will give estimates of the means and repeated ANOVA might also be tried.

2.8.6 Litter breakdown study

Litter break down studies usually employ litterbags, but these have serious limitations such as not allowing entry of many insects. There is an alternative method that has been described by Anderson and Swift (1983) in which the litter is in direct contact with the soil. This method has not been tested in teak and it is possible that it will be difficult because of soil sticking to the decomposing litter.

The experiment should consist of a split-plot, randomized block design with four replications and 8 treatments. These 8 treatments consist of 4 main plot treatments, which are to study litter collected at quarterly intervals (representing the main climatic periods). The subplots are the two methods-litterbags and non-bag techniques. For each of these combinations decomposing litter will be collected at monthly intervals for up to six months.

Ignoring the latter sampling over 6 months for now, the central statistical design is:

Source	df
Replication	3
Season	3
Error a	9
Methods	1
Season X method	3
Error b	12
Total	31

Note: It is important that the placement of the different seasonal samples be randomized within each replication, and the order of the paired methods be randomized also.

Litterbags should be made of nylon or similar and have a mesh size of 1.5-2 mm. The same mesh will be used to cover the samples inside the metal rings that are in contact with the ground.

Use about 25 g of material; the exact weight needs to be known for each bag but it need not necessarily be the same in all bags provided. Each can be identified in the field. Collect very recently fallen litter (litter can quickly loose some soluble nutrients). In some months the litter will be leaves but at other times other material will predominate. Use the main type of litter falling for that period.

Random samples of the litter put in the bags must be returned to the laboratory to obtain its moisture content and for analysis. Subsequent samples should be collected at monthly intervals. Dry weights should be recorded to nearest 0.1 g.

2.9 INTERCEPTION, THROUGH FALL AND STEM FLOW

Introduction: Dynamics of an ecosystem can be better understood by studying the movement of water through its various components since the nutrients in incident rainfall usually represents an input to the system. Incident rainfall in the forest canopy is dispersed in three ways—

1. Interception by canopy
2. Through fall
3. Stem flow

Interception refers to that part of the precipitation retained by the aerial part of vegetation, which is either absorbed by it or is evaporated. Forest canopy intercepts the incident rainfall so that its kinetic energy is dissipated by the aerial portion of the trees rather than imparting to the soil and hence, forests are effective agents in reducing soil erosion, flood etc. Except intercepted rainfall, rest of the amount of rainfall reaches the ground surface either by passing through tree crown, i.e. through fall (or) concentrated by the leaves and branches and later channeled down the boles to the forest floor, i.e., stem flow. Different vegetational types greatly influence the water regime of the area and may route precipitation through the basic pathways in different proportions.

2.9.1 Rainfall inputs

Rainfall in the open is important for two reasons. Firstly, it is

needed for interception calculations and secondly, for nutrient inputs. It should be stored frozen or close to freezing, prior to analysis of N, P, K, Ca, Mg, and Na.

For this reason the site needs to be reasonably close, yet one where extraneous contaminations are unlikely. The rain gauge should be elevated to avoid soil splash.

Two 10 x 10m representative plots were demarcated on each forest tree species stand. Circumference at breast height (Cbh) should be measured from ten trees representing different girth classes. Canopy cover (% ground surface and area (m^2 trees) should be measured through line interception (Misra 1968).

2.9.2 Through fall

To study the through fall the transect technique be used. Three transect collectors, each about 3 m in length and 15 cm in width should be randomly located in the plot. Each should lead to its own large collector that can be used for sampling the water for analysis and for measuring the volume of water. The three collectors will give a measure of variation, so volumes are being collected in each and samples for nutrient analysis need to be collected and recorded individually. Furthermore, the transect collectors may be moved periodically to ensure an even better estimate. Each time the collectors are moved, this should be noted just in case there are large fluctuations that need to be explained. It is envisaged that the through fall will be sampled in two ways. For most of the time samples will be collected at regular intervals. At other more intensive study periods, samples will be collected on a rainfall event basis. It is important that the size of rainfall events varies widely, from light showers to very heavy downpours, as this will assist in regression fitting and data interpretation.

Two types of data will emerge. One will give the annual through fall and include a measure of nutrients in it. The second will look at canopy interception (e.g. the amount of rainfall to wet the canopy) in relation to rainfall intensity. Interpretation of this data would be assisted by a measure of canopy area.

Through fall can also be measured by placing polythene containers beneath the canopy of each tree in a stratified random distribution. Flasks

should be moved to different positions after each collection. Cotton wool may be put into the funnel to prevent contamination with organic debris (Liken and Eatran, 1970).

2.9.3 Stem flow

This could be measured on five randomly selected trees within the plot. Care must be taken in:

1. Selecting trees to cover the diameter range so the trees are best selected on a stratified random basis. However, reject very abnormal trees (say with badly broken tops) or where the stem does not allow the collecting tube to be installed.
2. Using inert materials for the collecting spiral around the tree.
3. Using containers that do not allow light in, otherwise algae etc. will grow.

Again sampling can be a mixture of regular and even based. It should be possible to relate stem flow to tree diameter or basal area, using regression techniques, either on a seasonal, annual (or) size of event basis. The annual information can then be expressed on a land-area basis, based on the diameters of the trees in the main study plot. Confidence intervals or other measures of variation can be placed around these estimates.

Stem flow from the marked trees can also be collected through polythene collars (Liken and Eaton, 1970) into polythene container. For this a spiral polythene gutter of 4 cm diameter should be fitted in each stem with the help of iron nails of size 1 feet (2 nails per cm) and later sealed with paraffin wax. The gutter may be fixed at a height of 1.0 m above the ground surface. A plastic funnel must be attached to the lower end of the gutter connected to a polythene container. Cotton wool should be placed in the mouth of funnel to prevent the entry of extraneous material received. Stem flow for a tree may be calculated by dividing the stem flow volume by its crown area. Canopy retention can be calculated by subtracting the net precipitation (stem flow + through fall) from gross precipitation.

2.10 LEACHING

We recommended using tube lysimeters. These are made from small stainless steel tubes about 5 mm in diameter, with a ceramic tube

of about 2-3 cm length attached to their bottom ends. A narrow flexible plastic tube (as might be used in auto analyzers) goes down inside to the bottom of the tube. It is sealed as it passes out to the top of the tube, then goes through a rubber bung into a bottle via a thin metal tube. A vacuum is created in the bottle and this draws water from the soil through the ceramic, and the plastic tube into the bottle. This process may take several hours. The solution is analyzed for nutrient concentrations.

Tube lysimeters could be placed at two or three depths. Those at 20 cm would give a measure of the solution strength the main feeding roots are in. Those low in the soil profile would show when and if significant amounts of nutrients are being lost by leaching. To convert from concentration to a quantitative value of what is lost, then either soil moisture has to be measured down the profile, or reliance placed solely on estimated evapo-transpiration using models such as those by Berryman and Trafford (1974). Another approach may be to try and make a mass balance of a very mobile ion such as chloride. Probably, for the purposes of this study, estimating evapo-transpiration from climatic data is all that is required in the first instance. If very high concentrations are found at depth during some seasons of the year, then more detailed supplementary studies can be made.

For this study it is suggested that five randomly placed replicates be used and three depths studied (20, 50 and 90 cm). The tubes should be placed in groups of three. This number of replicates is chosen to give a measure of variation and also because sometimes the seal of the ceramic is broken. The tubes arranged in groups of three will be relatively easy to statistically test if nutrient concentrations change with depth. Begin the study at the start of the rainy season as the soil profile is wetting up. Take sample at regular intervals. The samples should be analyzed for NH^{4+}, NO_3, P_1, and other actions. Note that it is important to look at the form of N. Conductivity might also be useful if there are sufficient samples.

2.11 SEASONAL PATTERN OF TREE GROWTH

Part of the study envisages relating the nutrient fluxes during the growing season to tree growth. One easy way to do this is to install dendrometer bands on 5 or 6 trees (at breast height) within the plot and measure these at regular intervals. Dendrometer bands are made of thin,

non-corrodible strips of metal held in place by a light spring, so that they encircle the tree and fit snugly to the bark of the tree. They are fitted with a vernier scale, so changes as small as 0.1 mm in diameter can be recorded.

2.12 NUTRIENT MOVEMENT IN LEAVES

When the leaves flush there will be a large movement of nutrients from storage within the tree to the new growth. Similarly, there will be a movement of nutrients from the leaves back into the tree before the leaves are shed. This process could be studied in more detail by periodically collecting leaves during the growing season. We proposed that this be done at this site, because it will give better information on the internal cycle and demand for nutrients. It ties in with the biomass study also which gives a measure of how much and where the nutrients are in the tree and also the total amount of mature foliage. As there will be regular work going on in the plot, collecting this information will not add greatly to the workload.

Access is needed to branches in full sunlight. On each sampling date, take three complete leaves from each tree to give 12 leaves per sampling date. These leaves should be about average for that time of the year but be randomly collected. Collect at monthly intervals, or every two weeks, if rapid changes are occurring. The number and dry weight of the leaves, from the separate trees should be measured and recorded and then all 12 combined for analysis of nutrient concentrations. Insect damage to the leaves may occur, particularly late in the growing season. Therefore, it is recommended that an estimate be made on the amount of damage to each leaf. Leaf eating insects are part of the nutrient cycle.

From this data, nutrient contents can be estimated on a per leaf basis, and also, using the tree biomass data, the total movement (on a per hectare basis) calculated. The information will also be useful in defining the best time to sample teak for nutrient diagnostic purpose.

2.13 OTHER CLIMATE DATA

It would be useful to have access to or actual measurements of standard meteorological data. A weather station in the open would be ideal.

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3

METHODS OF STUDYING NUTRIENT REQUIREMENTS OF FOREST SPECIES

3.1 INTRODUCTION

Recent investigations in many countries have shown that one of the reasons common for sub-optimal growth in nurseries and plantations is the absence of one or more essential nutrients. Afforestation of various sites in India also has not always led to high production. This may be due to the fact that many of these sites being marginal in character might not have among other things adequate amount of nutrients to sustain good growth. It is on such sites that the knowledge about the nutrient requirement of a species and the use of chemical fertilizers in forestry will be of paramount importance. Numerous trials have shown that in forests, particularly in the plantations, the yield could be increased manifold if proper dose and regime of application of fertilizers could be worked out (George, 1977, Shanmughavel, 1995).

This chapter purports to fulfill three objectives. In the first instance, an attempt has been made to discuss briefly and critically various methods in the study of forest nutrition. Secondly, to summarize the work done in India particularly in view of the fact that many authors (Nickolas,

1957, George, 1977) have emphasized that very little information of the nutrient requirements of forest plants is available from tropical countries, and thirdly to indicate future course of research.

3.2 AIMS IN FERTILIZING FORESTS

Following are the important objectives of fertilizer application.

(1) To ensure increase in productivity at economic levels of fertilizers.
(2) To increase and maintain fertility level with a view to sustain high productivity.
(3) To accelerate growth and help establishment of transplants in the early stages against competition from weeds.
(4) To obtain quality seeds in sufficient quantity from seed orchards and plus trees.
(5) To improve vigour and resistance of multipurpose trees.

It is essential to have preliminary information which will elucidate the following five basic principles:

(1) What are the limiting nutrient requirements of the species to be used?
(2) What capacity do the existing soil types have for supplying these requirements, both from the viewpoint of reserves and rates of release?
(3) What course will soil fertilizer reactions take when fertilizers are applied and at what rate will these reactions proceed?
(4) What side effects will result from application of fertilizer at various rates?
(5) What chance is there that treatments can be applied efficiently under a given site condition?

A clear understanding of the above questions requires a thorough knowledge about the behavior of the species, soil types, fertilizers and even other conditions prevailing on a particular site. Many methods, each one of them having its own advantages and disadvantages, have been adopted in solving these questions which are briefly discussed under the following heads.

(A) 3.3 DIFFERENT APPROACHES ADOPTED IN THE FOREST NUTRITION RESEARCH

1. Visual symptoms.
2. Pot analysis.
3. Soil analysis.
4. Tissue analysis (foliar diagnosis).
5. Indicator plant methods.
6. Substitution methods.
7. Field trials.

(B) 3.4 COMBINATION OF TWO OR MORE METHODS

3.3.1 Diagnosis of visual deficiency symptoms

(a) Pot Culture:

The most preliminary and rapid method to determine a nutrient deficiency is by observation of visual symptoms. The standard procedure consists of growing plants in sand or water cultures (sand cultures being preferable to water cultures as they provide a solid rooting medium and also provide better aeration) under controlled conditions and fed with solutions of pure chemicals. Deficiencies of the individual nutrient elements are created in the nutrient solution by omitting each separately from the complete nutrients solution and the symptoms of each deficiency exhibited by the plant are recorded (Wallace, 1951).

This method is especially useful in the assessment of effects of various treatments (fertilizing, thinning, mulching, etc.) where other measurements fail for some reason.

Difficulties and inaccuracy in the interpretation of results obtained in such experiments under field conditions arise when a plant suffers from lack of more than one nutrient or when a deficiency of one nutrient combines with an excess of another, or even when the symptoms are modified by the environment (Vanclay, 1992).

However, this is essentially a qualitative approach for nutrition studies. It is less reliable in the case of mild deficiencies, i.e. in the range of so called "hidden hunger" in which growth may be substantially depressed despite the absence of recognizable "distress signals". Thus visual symptoms may be frequently valuable indicators of nutritional stress, but the symptomatology is, at best, a subjective and inexact science. Such studies need to be followed by factorial experiments where various levels of nutrients are tried under controlled conditions reflecting nutrient interactions.

(b) Foliar Spray:

In recent years, it has become increasingly popular particularly in fruit trees to apply nutrients as foliar sprays. The usefulness of foliar application of nutrients depends on the following circumstances: (a) the existence of special problems that may not be coped with as well by application of fertilizers to the soil or by soil amendments (b) satisfactory response to the nutrient sprays, (c) economic materials and methods of application. Because of fixation problems, micronutrients e.g. Fe, Zn, Mn and Cu are usually applied as foliar sprays. This method is also useful where a temporary control is needed or response to soil treatment is slow or to correct the balance of nutrients when it is not possible through soil dressing (Bould and Hewitt, 1963).

3.3.2 Pot trials

In forestry, the time scale is strongly against the experimenter. It is presumed that even with rapidly growing species, it will take about seven years to discover from field trials alone whether the treatments in an experiment are adequate as to the rate and nutrient tested. Commercial evaluation will take as long again. Therefore, prior to beginning the field trials, many workers have adopted a more physiological approach, viz., experimenting with seedling or transplants in pot or solution culture in order to gain basic information about the nutritional behavior of a species in comparatively shorter period. The special value of pot cultures depends more on the fact that they can eliminate and then partly reintroduce under controlled conditions, selected combinations of the complex of factors comprising a soil environment. Cultural methods permit the study of interactions of deficiencies and excesses at accurately determined levels (Hewitt, 1970). Some of the obvious advantages of these methods are (i) more complicated experimental designs can be used without prohibitive cost, (ii) variation in growth due to other sources than nutrients including those of genetic origin can be reduced to the minimum, (iii) there are greater possibilities of evaluating total growth response in more details and more correctly than in forest stands, (iv) most of the possible indirect effects of fertilizers can be entirely eliminated in pot cultures, (v) in sand and water cultures, nutrient interactions noted or suspected in the field can be tested (Gentle and Humphrays 1968).

There are mainly three kinds of pot cultures being used for studying nutritional behaviour of species, viz., (i) sand culture, (ii) water culture and (iii) soil culture. Sand cultures are simpler to manage and provide more satisfactory growth medium for most plants. They have the solid rooting medium with better aeration and permit greater latitude in concentration of toxic elements. Phenomena like root contract and ion exchange can be studied more easily in sand cultures. Water cultures on the other hand, benefit more conveniently the change of nutrient solutions at specified times and roots can be thoroughly rinsed if desired. Contamination by other nutrients can easily be avoided. But water cultures require special efforts for aeration and to check algal growth on the walls of the containers. Soil cultures or the so called soil bio-assays have been used with good effect to make direct biological measurements of the nutrient supplying powers of forest soils. Basically the technique consists of growing tree seedlings in sample of soils to be tested, and measuring the response obtained when nutrients are added singly and in all desired combinations. Pot cultures have also been used to study relative merits of different culture solutions, forest hardiness, drought resistance and even potential water requirements of forest species.

Some of the disadvantages of such cultural experiments which reduce their usefulness to a great extent are, (i) differences in plant growth observed in different media viz., sand, solution, gravel, mulch, compost or soil have not been established and hence results of these experiments in different media are not comparable; (ii) in sand cultures wetting and drying cycles are too artificial unless very expensive equipments are used. Root cat ion exchange action is not complemented with the natural soil action exchange mechanism of maintaining buffering action which is inherent during clay and humus portion of most natural soils; (iii) algal growth in containers and bacterial infection of roots in solution culture are difficult to control under some pH and nutrient regimes; (iv) pot trials using the soil which may be ecologically very different from the same amount of soil *in situ* are of limited value because of the change in physical properties due to being a very limited part of the profile. Even the monolith soil samples are disturbed to some extent. Subsequent drainage and drying cycle conditions cannot be compared with those of the natural soil, nor can soil temperature regimes be simulated in pots.

Even the chemically important changes in the availability can occur due to differences in microorganism population resulting in depression or stimulation of growth. K-deficiency, for instance, has been noticed in pots at early stages whereas field experience reveals no such deficiency in these cases; (v) the nutrient uptake and requirements of seedlings may be different from that of adult trees because of differences in anatomy and cell physiology. For example, visual symptoms of K-deficiency differ considerably between seedlings and adult trees. It has been noted that soil bioassays for reasons, which are not fully understood, tend to exaggerate the response to addition of phosphorus. Kauland Mathur (1971) found differences in branching habit by the deficiency of N and P in seedlings of *Eucalyptus sp.* which may not occur under natural conditions in adult trees; and (vi) the results are not immediately applicable to the field conditions because no way has been found to relate absolute levels of nutrients used in pot or solution cultures to those found in field soil. Field trials (and in some cases, supplemented by other methods) on the basis of these experiments are necessary to get conclusive results.

To sum up their usefulness for practical purposes, it can be said that various kinds of pot trials, in spite of the above mentioned limitations and need for improvement in techniques have an important part to play in providing excellent information on nutrient physiology of tree seedlings.

3.3.3 Soil analysis

The value of soil analysis in the study of nutrient requirements of forest species has to be considered separately for tree seedlings in nursery beds and fertilizer needs of forest plantations and second growth stands. During the past three decades, foresters in advanced countries have made remarkable progress in the soil requirements of nursery soils. Avoidance of excessive stoniness and a silt plus clay content between 15 and 20 percent obviate difficulties of cultivating or transplanting and assume reasonable water retention. Impermeable or calcareous substrata less than 1.2 m from surface should be absent. The top 15 cm should contain the appropriate mycorhiza, around 2% organic matter, 0.07 per cent total nitrogen, 10 kg/ha of available phosphorous, 80 kg/ha of available potassium and 1.5 and 0.5 meq /100 g respectively of exchangeable calcium and magnesium. Soil pH should be between 5 and 6. It is well

known that nursery stock removes appreciable quantities of plant nutrients, which have to be replenished in routine fertilizer treatments.

Study of nutrient requirements of plantations and forest stands by means of soil analysis presents some formidable problems and has not proved very reliable partly because the investigators have tried to establish some correlation between the nutrients and soil biomass components. Moreover, very often one or few of several soil factors; both physical and chemical have been picked up for correlation studies, which is risky. However, multiple correlation studies by electronic computers may greatly facilitate provided correct parameters are used.

George (1977) recommends prior analysis of soils in planting sites to ascertain the presence of an adequate supply of essential nutrients. Such analyses are particularly desirable in regions showing poor growth of native stands, or plantations. As a rule, the analysis could be limited to the upper 6-inch layer of soils as its composition usually reflects the properties of the substratum and is of decisive importance in the initial growth of planted trees.

Some recent works have emphasized the importance of parent rock in the study of nutrient requirements of forest trees. Forest trees have a long span of life and their roots are capable of extracting more nutrients from soil minerals than are those of agriculture crops not so much because of higher efficiency as of longer persistence.

Some of the factors which have a great bearing on the turn over and nutrient availability in the soil and ultimately on the value of soil analysis as a guide to fertilizer needs of the forest crops are— (i) the complex nature of humus layer, (ii) availability of moisture, (iii) aeration and (iv) biological activity of soil organisms. The availability of nutrients after the application of fertilizers depends to a great extent on the situation of these factors and a careful study is needed in any study on soil/ fertilizers.

There are certain aspects which make soil analysis approach limiting and less reliable particularly the ones mentioned below:-

(i) Soil sampling

As a result of differentiation of distinct horizon, often differing appreciably in composition, most forest soils are markedly heterogeneous.

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On the other hand, most trees are long lived, deep rooted and exploit large mass of soil. Therefore, there is a controversy about the horizon of the profile, which should be studied in detail. These factors introduce considerable soil sampling problems particularly in tropics where root penetration may extend over several meters. In practice, sampling is done up to 3 m depth.

(ii) Method of extracting nutrient

Soil samples can be analyzed in many ways, viz., HCl soluble nutrients, exchangeable basis, and determination of total exchangeable ions, available nutrients or measurements of ions absorbed by ion exchange resins mixed with soil to determine their nutrient contents. It is not yet definite which of the above method will give a true picture because of the dynamic character of the available nutrients in soils. For instance, change in the amount of nitrate nitrogen in soil may be caused by the change in the rate of decomposition of nitrate or ammonia.

(iii) Growth factor

The dynamic nature of growth of the plant itself introduces problem for predicting the fertilizer needs. An intensely growing forest stand may exhaust the soil supplies of easily soluble nutrients before growth ceases resulting in a negative correlation between yield and soil nutrient content.

3.3.4 Tissue analysis (Foliar diagnosis)

The method of plant analysis is based on the concept that plant itself is the best indicator of soil nutrient availability and physiological uptake and the analysis of the plant tissues constitute a natural biological rather than an artificial extraction (soil analysis) method reflecting integration of numerous inter-related factors affecting the availability of nutrients.

(i) Sampling

Strict adherence to sampling standards is a pre-requisite in foliar analysis particularly in case of trees having long span of life and usually a large well developed crown. The important aspects in sampling procedure are (i) age of leaves and number of trees, (ii) season, (iii) position in crown, (iv) shading, (v) fruiting, (vi) weather conditions, (vii) time of day and (viii) attack of parasites. Adhering dust particles and pollution in industrial areas may also act as a source of error. This

indicates the need for standardization of sampling procedures. According to most investigators conifers should be sampled at the end of the growing period and the deciduous trees just before autumnal yellowing. Regarding the position in the crown it is agreed to sample as near the tip as possible, and in conifers young needles from a particular whorl.

(ii) Year to year variation in nutrient content of foliage

Generally there is appreciable difference in the level of certain elements in different years. Srivastava et al., (1972) found large variation in litter fall and composition from year to year (The factors responsible for the variation are rain and drought, leaching from leaves and even intensity of transpiration stream. For definite conclusion it is therefore advisable to sample leaves for more than one year.

(iii) Handling and preparation of samples

Rapid killing and drying after collection is necessary to avoid decomposition changes and apparent increase in dry weight and mineral content by continued respiration.

(iv) Unit of expression

General practice is to express macro-elements in terms of percentage on dry weight basis and microelements in ppm (parts per million). Several authors (George, 1977, Shanmughavel, 1995), have used ratios between the various elements (percentage per 100 mg) instead of or together with dry weight percentage, some of which viz., K/Ca, K/Mg, Mg/Ca may be the expressions of antagonism between the cat ions in question. Mengal and Kirkby (1987) by using a standard punch of one cm^2 expressed results on leaf area basis and Kessler (1961) based their results on the amount of nutrients per 100 needles.

(v) Interpretation

Interpretation of data obtained from leaf analysis is of decisive importance and presents some difficulties because of numerous interactions, ion antagonism and differential uptake which are a rule rather than an exception. Further, the amount of a nutrient in the foliage at any time depends not only on the availability in the total mass of soil accessible to root system but also on the factors that influence the growth of the plant. Therefore, knowledge about the dynamic nature of growth and nutrient, their interaction and movement in plants, specific functions,

varying requirements of plants in different seasons and ages together with the role of environmental factors is essential for correct interpretation of the data. A fair amount of knowledge has been accumulated on these but much still remains to be done and indicate a pressing need for intensive basic research.

In many cases, nutrient interactions coupled by growth are so complicated that simple correlations are not possible. If growth increases more than the nutrient uptake in a vigorously growing stand, the result will be lower concentrations (a dilution effect or "false antagonism"). This is particularly observed when supply of the same nutrient is increased from extreme scarcity to optimum. On the other extreme there is often a tendency for luxury consumption, i.e., accumulation of nutrients beyond the optimum level without corresponding growth (Leyton and Armson 1956).

In the event of multi- elemental deficiencies, a number of workers have analyzed the relationship between growth and concentration of different nutrients in the foliage in terms of multiple regressions, which has been facilitated by the modern computers. This approach implies that height or site index is a function of nutrient status and factors making significant contribution to the regression of height on foliage composition can be distinguished from factors related to growth by virtue of their internal relationship with the significant factors.

Another approach for development of diagnostic issue analysis may be found in fractioning the organic and inorganic compounds in plant part. It is a well known fact that a lack of plant nutrients may cause disturbances in metabolism. Some of these effects may be specific enough for diagnostic purposes (Kessler, 1961).

In the light of the above discussion, it is evident that the methods of foliar diagnosis if used with due care in sampling and interpretation will be highly useful in determining nutritional imbalance in nursery stock as well as plantations and forest stands.

3.3.5 Indicator plant method

(a) The phytosociological approach

The method is based on the concept that each species has got certain ecological amplitude, i.e., it can thrive (as vigorous specimen)

under certain environmental conditions and hence is a measure of those conditions. Thus it is based on the cause-effect relationship where the effect is taken as a sign of cause (Srivastava et al., 1972). In literature many examples can be found where indicator species have been sorted out and certain correlations have been established with the growth and productivity of the dominant species (Cajender, 1926), with the occurrences of natural regeneration (Switzer et al 1972) and sites suitable for afforestation with exotic species (Havel 1970). According to George (1977) for a practical use in silviculture, it is not necessary to know exactly about the demand of the indicator plant: it is sufficient if the sites can be classified into units with different properties concerning actual or potential use in under forest management with the help of indicator plants.

Yet there is another type of indictor, so called "nitrate plants" a term used by Goodwin (1954) for plants demanding nitrate in soil and accumulating in leaves to become established and thrive. It is also possible, sometimes to use microorganisms as indicators of the soil supply of nutrients. Aspergillus has been used extensively for Mo determinations in arable soils. However, there are no such examples on forest soils.

(b) Use of indicator plants for extraction of nutrients from the soil

In this method, indicator plant is grown in pots or in the field to extract nutrients to ascertain the amount of available nutrients. The most widely known pot test method is that introduced by Freez, 1961 in which red rye seedlings is determined after 17 days. The uptake from the soil is then calculated. Tables are available to show the quantities of nutrients that should be available for food growth of various crops. A similar method with tree seedlings as test plant has been used extensively in forest soils (Hibberred, 1991). However, as in the case of soil analysis and pot culture using soils, in this case also, it is doubtful whether the method gives a correct picture of the amounts of nutrients available in forest soil *in situ.*

3.3.6 Substitution method

In this method, an attempt is made to determine the total nutrient consumption by a forest stand by analyzing harvested material as well as litter. This kind of work was the first serious attempt to obtain

information on forest nutrition. Thus George (1977), studied the amounts of nutrient content in plant parts and explained site deterioration after centuries of litter removal. This approach gained immense importance after the article by Rennie (1955) and after that many workers (George, 1977, Shanmughavel, 1995), have studied the mineral cycling making a complete balance sheet for nutrient supplies and losses in different ecosystems.

3.3.7 Field trials

Field trials are the traditional method of testing fertilizer responses. The data can often be used to determine precise quantitative relationship between the levels of nutrients and yields. Factorial experiments can be useful in studying the interactions between mineral nutrients and deficiencies resulting from lack of balance between elements. Field experiments, however, have to be used at final stage of work. According to Gentle and Humphreys (1968), if used for primary diagnosis, they run the risk of entirely missing the crucial deficiency or failing to differentiate responses between the essential and non-essential elements in the fertilizer. They may indicate nothing about the mechanism of response or why response continues or fades out. In order, therefore, to avoid wastage in time by using "hit or miss" technique, the experimenter needs to collect all available information on the nutritional behaviour of the species and the soil type where the species is to be tried prior to the beginning of the field trials.

In addition, a few practical criteria merit particular attention when field experiments are designed (Gentle and Humphreys 1968):

(i) The object of the experiment should be clear and as simple as possible because of the necessity of keeping down the total area of the experiment to a reasonably uniform area (as in the forest it is often difficult to find large uniform areas).

(ii) The object should be pertinent to the subject. It is, for example, of little value to experiment with K and P in a stand showing nitrogen deficiency. Many fertilizer treatments proved inefficient because the applied fertilizers did not include the elements necessary for the correction of existing nutrient deficiencies.

(iii) The experiment should conform as far as practicable to future forestry practice in respect of spacing, site preparation etc,

(iv) The design should be simple enough but statistically sound. Thus the plots should be randomly assigned at least in duplicate for each treatment and combinations.

(v) The plot should be spacious enough to carry through at least two thinnings so that silvicultural interactions are tested.

Beside the above, it should be ascertained as early as possible that a certain treatment has desired effect and no important side effect. Because, the indirect effect of fertilizer treatments are even more difficult to interpret. To avoid this difficulty, the effect of treatment can be tested by treating plants with some other means, say by spraying or stem injection in case soil application of fertilizers is ineffective or has profound side effects.

There are numerous reports in which application of organic matter has increased forest growth. Instances have also been reported in which cultural operations like soil working, weeding and trenching have improved growth of young trees. Such treatments should not be used while investigating nutrient requirements with the help of field trials. Their effects are too complex, affecting micro-biological conditions as well as soil chemical and physical properties. It is then difficult to distinguish between the effects of fertilizers and such treatments.

One more precaution necessary in field trials is to transplant the seedlings as naked plants (though it involves the risk of mortality of a few seedlings) and not along with pot soils, as has been the practice lately since the adoption of polythene bags as pots. In the later cases, the plant roots remain confined for a year or two to the pot soil, which is well prepared and rich in nutrients as compared to the soil on planting site. Therefore, the fertilizers applied during this period go a waste, either due to leaching or utilized by the ground floor vegetation.

It should also be noted that some commercial fertilizers contain magnesium, sulphur or trace elements in addition to the major nutrients. Therefore, special attention must be given to the choice of the fertilizers if the effect of the various nutrient elements is to be assessed correctly.

A positive reaction to an added nutrient by the sample trees can usually be taken as evidence for a deficiency of that nutrient. This procedure is expected to indicate within 5-15 years whether or not the

procedures used are likely to be applicable on large scale forestry, and if so whether biological and economic objectives are likely to be achieved. The more closely experimental design confirms to pilot plot operation, the more expeditiously can useful information be fed into the normal operations. As a rule, a year spent in this way is worth about 5 years spent filling in data deficiencies later in the life of the field experiment (Gentle and Humphrays 1968).

Field trials with fertilizers were initiated during fifties of the past century in European countries. In most trials positive results were obtained with the use of green manures particularly lupin and with the application of organic manures, e.g., litter and slash. A considerable improvement in the growth of plantations due to application of lime and crushed rocks rich in bases was observed. The effect of soluble mineral fertilizers was inconsistent and often short lived (Wider and Lang, 1982). Wood (1960) attributed conflicting results of early fertilizer trial to the following causes: (i) insufficient knowledge of soil chemistry, action of fertilizers and nutrient requirements of tree species, (ii) competition of weed vegetation which developed vigorously on the fertilized soil, and (iii) occasional drought or winter kills which not only annulled the benefit of the fertilizer treatment but made such treatment harmful.

However, the scheme is so large and the climato-edaphic, physiographic and even biotic conditions will vary so much besides the personal errors caused due to so many separate terms looking after the experiments that it will be extremely difficult if not impossible to sort out the effect of fertilizers. The design of the experiments also appears to be large so as to make it difficult to handle the experiments or even to find out uniform area for laying out experiments. Moreover, it appears that no attempt has been made to find out either the nutrient requirements of the species (the three species may vary) or nutrient deficiency symptoms in plants before deciding upon the levels.

The better alternative would have been to carry out field trials by 4 teams exclusively appointed for the purpose in 4 regions (North, South, Central and Eastern) on 2-3 varying soil and climatic situations in each region after a systematic analysis of soils determining the possible deficient nutrients and keeping the experiments as small as possible, may be in a single or double nutrient combinations. Experiments should have

simultaneously been laid out to determine the method and time of application, frequency and source of fertilizers and its economic aspects. Along with soil analysis, foliar diagnosis method should have been applied to find out the response to applied nutrients. These teams if necessary would have also conducted pot cultures to study any special problems arising out of their field experience regarding antagonistic, synergistic or other interaction effect.

3.4 COMBINATION OF TWO OR MORE METHOD

Since no single method can give complete and reliable information on the nutrient requirements of forest species, in practice, several possible combinations of two or more methods have been used. Pot cultures with seedling have been combined with observations of deficiencies and toxic symptoms. This was further combined with the chemical analysis of seedling. This approach has been very useful in nursery work and many observations on visual symptoms, plant nutrient uptake and growth were found to be true over a wide range of conditions including mature trees in forest stands (Wallace, 1951).

The method of foliar diagnosis combined with the field experiments and often supplemented with pot and solution culture experimental data will be useful in indicating and double checking as to which nutrient should be augmented. This combination was used by Morey et al (1985) to differentiate a number of species as "Nitrogen demanding intermediate" and "Nitrogen deficiency tolerant". Several later workers followed this approach and tried to standardize the foliar analysis data with the help of field experiments with or without pot cultures (Tamm, 1960, Wallace, 1951). The use of exponential curve has not been common; instead there is a trend to use multiple correlation method in the interpretation of experimental data (Wallace, 1951, Leyton and Armson 1956).

It appears that the method of foliar diagnosis combined with experiments in the field, or both in the field and under controlled conditions, forms a very useful approach in forest nutrition research. In fact Tamm (1960, 1964) calls it, a combination of extensive field experiments with foliar analysis as the best approach to the study of ecological nutrient requirements of various species and Gentle and Humphreys (1968) feel that foliar crop logging procedures will be a regular feature in near future to make certain that applied nutrients are

being efficiently absorbed and to control rates of release from various sources more cheaply and accurately than would be possible from soil analysis.

Along with the field experiment and foliar analysis, soil analysis data can be combined usefully to determine the fertilizer source, method of application and on which soil type to change to another source. Phosphorus, for example is very mobile within the tree so that a few tree roots contacting the bond are adequate to supply it to the tree. Calcium mobility within the tree is at the other extreme so that bonding is not correct solution, where calcium and phosphorus deficiencies are being remedied together (Gentle and Humphrays, 1968).

3.5 THE NEED FOR INTENSIVE RESEARCH ON FOREST NUTRITION

The use of fertilizers in forestry is well established in many parts of the world and there is clear evidence that the rate of wood production can be significantly increased on many sites by the application of deficient nutrients. There are classical examples of dramatic responses to phosphate and even certain micronutrients in parts of Australia and New Zealand (Williamson 1983). The duration of the effect of applied fertilizers varies from 5 to 40 years, depending chiefly on the type and quantity of fertilizers applied and the nature of the soil. Climate and drainage pattern also add to the effectiveness with which the nutrient cycle functions. It is also realized that the species at the lower limit of nutritional adequacy are unduly susceptible to disease and insect attack. Moreover, the wood produced by fertilized trees is little, if at all, inferior to that produced by unfertilized trees (Swan, 1967).

The most difficult problem, not yet solved satisfactorily is to determine the capacity of different soils to transmit the effects of fertilizers to the growing stock. This capacity depends upon several conditions including the supply of soil, water, air and nutrients, climate and length of growing season. According to Willey (1985), the concept of fertilizer responsiveness of soils should be placed in the foreground of all forestry fertilization work and deserves elaboration. At the same time, it is essential to study the effect of lack of essential nutrients on the anatomical structure both shoot & root particularly the growing points. These are the most sensitive parts and the first to be influenced by the deficiency

of a nutrient. Another field, which requires attention, is to study the effect of lack or application of fertilizer on root regeneration potential. The roots are usually the first organs of a plant to respond to the environmental changes and success of any species depends largely on the adaptability of roots to these changes.

As far as the tropical countries in general and India in particular are concerned, it is evident that very little information on nutrient requirements of forest trees is available. This is partly due to the fact that in tropics, a tendency is prevailing where the climate and physical properties of soil are the most important factors for forest growth. Although, it may be true in case of well-stocked, scientifically managed natural and virgin forest stands, the same cannot be said about the man-made forest ecosystems, many of which are being established on marginal soils but with the hope of quick and best returns on sustained basis. During the last decade or so, stray attempts have been made to study some aspects at the Forest Research Institute through pot cultures and foliar analysis but with little follow up action in the field. However, sincere and well thought out attempts are needed on intensive basis to develop efficient methods to suit diverse situations on the commercial use of fertilizers to bring research data to operational feasibility. By the time this is achieved, it is hoped that the country will be self-reliant in fertilizer production and quantities required in forestry operations will be easily available. Unless the afforestation program is ready to provide soils of reasonable fertility, fast growing species and even the improved varieties resulting from research in tree breeding will not give anticipated yield and the areas of the struggling non merchantable plantations will only serve as breeding center for parasites. Therefore research of forest nutrition is urgently required both in the context of production and conservational functions of man-made forest ecosystems in the interest of harnessing the environment in the service of humanity.

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4

CHEMICAL ANALYSIS OF WOOD

4.1 INTRODUCTION

This chapter is mainly intended to provide methodology in the proximate chemical analysis, pulping and paper making characteristics of the soft and hardwoods. The characteristics may vary somewhat with growth conditions and age of the trees of a specific plantation.

4.2 PROXIMATE CHEMICAL ANALYSIS

4.2.1 Analysis of Wood

In order to be clear (before the description of the method) a general scheme of the protocol is given in Fig 4.1 with modifications (Alaudin et al 1971, Bhat and Guha 1952, Bhat et al 1955).

Scheme of the Procedure

Equipment

a) Electrical saw
b) Sieve having 65 meshes/sq. cm. and 200 meshes/sq. cm.
c) Soxhlet extractors
d) Filtering crucibles with fritted disk of coarse porosity G2 and G3

e) "Kipps" apparatus using NH_4Cl and H_2SO_4 for the production of gaseous HCl flow.

Reagents

1) Benzol
2) Ethyl alcohol at 95 °C
3) NaOH solution 5% by weight
4) Chlorine gas

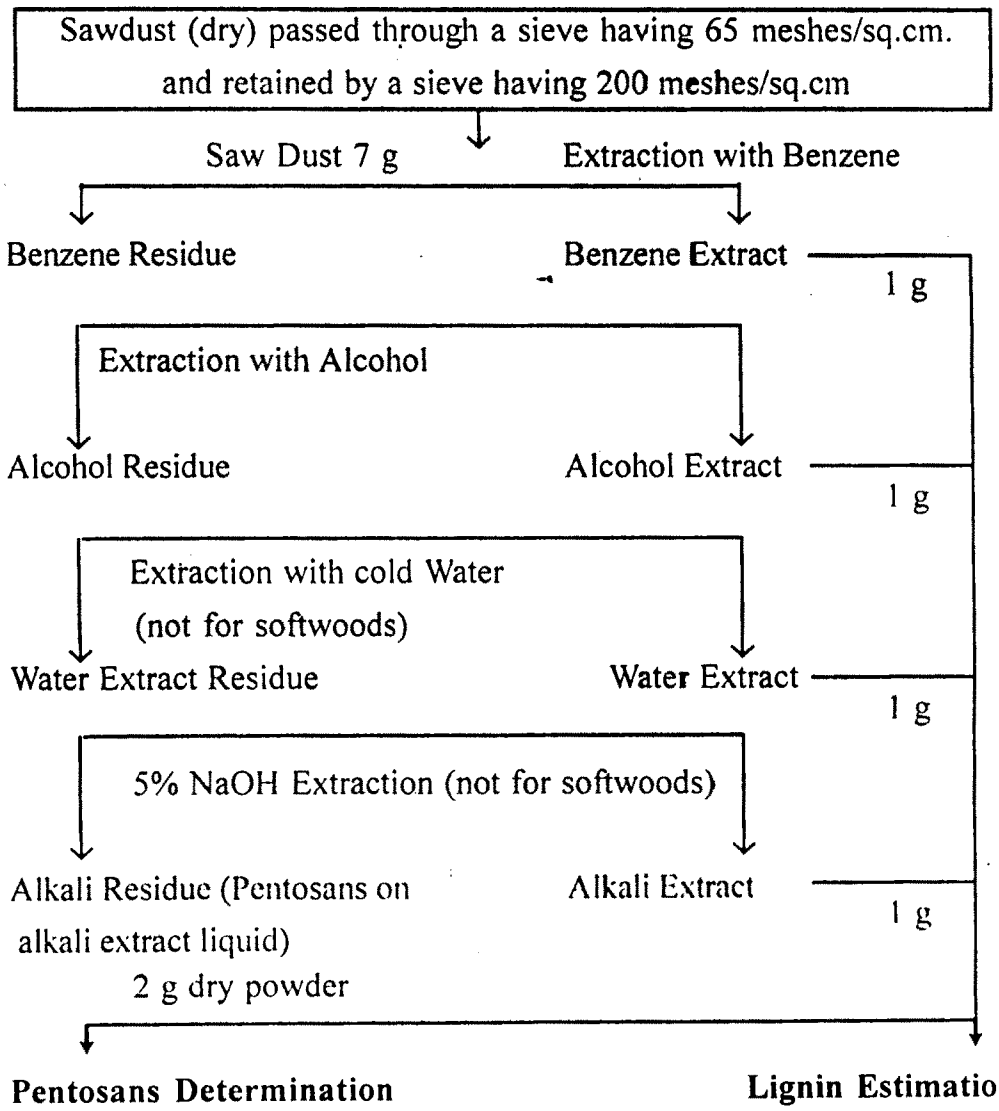

Figure 4.1

NOTE: For softwoods the determination of CROSS- BEVAN cellulose is made after the first two benzene and alcohol extractions (Alaudin et al., 1971). Each determination should be made twice.

4.2.2 Preparation of the wood sample

The wood is reduced into sawdust by means of a saw. The sawdust is sieved on a sieve having 65 meshes per sq. cm. and 200 meshes per sq. cm. The material retained by the second sieve is called "Average Wood" and is used for the chemical analysis.

Procedure

4.2.3 Benzene extraction

7 g of sample of average wood may be dried in an oven at 100°C. The dried content needs to be extracted with benzene for 6 hours in Soxhlet; the extract should be dried at 100 °C and weighed.

$$\text{Benzene extract \%} = \frac{\text{Extract weight} \times 100}{\text{Bone-dry wood weight}}$$

4.2.4 Alcohol extract

The residue from the previous operation (Benzene extraction) needs to be extracted for 6 hours with 95% alcohol. The extract may be dried at 100 °C and should be weighed.

$$\text{Alcohol extract \%} = \frac{\text{Extract weight} \times 100}{\text{Bone-dry wood weight}}$$

4.2.5 Soluble matter in cold water

The residue from the alcohol extraction needs to be dried at 100°C and should be digested for 24 hours with 400 ml of cold water. It may be then filtered through a filtering crucible with fritted disk of coarse porosity G3 and washed and dried at 100°C for 10-12 hours and should be weighed.

$$\text{Cold water extract \%} = \frac{\text{Extract weight} \times 100}{\text{Bone-dry wood weight}}$$

4.2.6 Soluble matter in 5% NaOH solution

The residue from the soluble matter in cold water may be treated with 100 ml. of 5% by weight NaOH solution for 24 hours, and the solution should be filtered through the same filtering crucible as used before. The residue needs to be washed with 100 ml of 10% (v/v) acetic acid solution and then with distilled H_2O. The residue at neutral reaction of the filtrate may be dried as before and should be weighed.

$$\text{Alkali extract \%} = \frac{\text{Extract weight} \times 100}{\text{Bone-dry wood weight}}$$

4.2.7 Cross Bevan Cellulose (with pentosans)

Two grams of dry material, which had undergone above 4 extractions, should be transferred to a filtering crucible with fritted disk of coarse porosity G3. The filtering crucible may be connected to a vacuum flask immersed in a proper ice cooling container.

It needs to be washed with warm distilled water, and after having put the ice into the container, a chlorine gas flow under slight vacuum should be passed through the filtering crucible for 5 minutes (velocity of the flow: 2 bubbles per second). Then the sample needs to be washed 2+3 times with a 1% by vol. SO_2 solution (about 100 ml). The vacuum may be then disconnected and the fritted crucible filled up with 1% soda solution (the material changes colour to brown). It should be digested with soda for 5 minutes. The vacuum should be connected and the chlorine flows again through the filter. This double treatment needs to be repeated until the material contacting the soda remains white. The solid matter should be dried and weighed. Pentosans can be determined on the residue.

Cross - Bevan cellulose:

$$\text{Wood theoretic weight} = \frac{\text{Wood weight after the 4 a.m. extractions} \times 100}{100 - (\text{sum \% of 4 extractions})}$$

$$\text{Cross-Bevan cellulose} = \frac{\text{C.B. residue weight} \times 100}{\text{Wood theoretic weight}}$$

4.2.8 Lignin

From the above four extracts, samples of 1 g from each fraction may be placed in four single test tubes and should be treated with 12 ml, of concentrated HCl. Each test tube is closed with a rubber stopper, having an inlet tube going down almost to the bottom and an outlet tube. Through the inlet tube a flow of HCl gas should be passed which may be supplied by a Kipps apparatus with NH_4Cl and H_2SO_4. After this stage the test tubes may be left closed during 24 hours, the contents then mixed with water and filtered off, and washed thoroughly until the acid reaction of the filtrate disappears. Later the sample may be dried at 100°C for 8-10 hours and weighed.

$$\text{Lignin (\%)} = \frac{\text{Extract weight} \times 100}{\text{Wood theoretic weight}}$$

4.2.9 Ash

It is determined on 2 g of wood.

$$\text{Ash \%} = \frac{\text{Ash weight} \times 100}{\text{Dry content of wood weight 2}}$$

4.2.10 Moisture

It is determined on 10 g of wood.

$$\text{Moisture \%} = \frac{\text{Dry wood weight} \times 100}{\text{Moist wood weight 10}}$$

4.3 DETERMINATION OF PENTOSANS

Equipment

a) Normal distilling apparatus equipped with graduated funnel for filling HCl into the distilling flask.

b) Filtering crucible with fritted disk of coarse porosity 11 G3 (gamma) or 11 G4 (delta).

Reagents

1) HCl solution 12% by volume (D = 1.06).

2) Hydrochloric phloroglucin solution free from resorcin prepared by dissolving 74 g of phloroglucin in 12% by vol. HCl, then diluted to 10 liters with 12% HCl. The possible presence of resorcin may be tested as follows: a small quantity of phloroglucin is dissolved in few drops of acetic anhydride and brought to boiling; at this moment few drops of concentrated sulphuric acid are added: a violet color indicates the presence of resorcin.

3) Aniline is prepared by adding acetic acid or hydrochloric acid drop by drop to a mixture of equal volumes of aniline and water until a clear solution is obtained.

4.3.1 Preparation of the sample

One gram of bone-dry wood sawdust may be weighed and should be placed into the distilling flask. 100 ml of 12 % HCl should be added through the proper funnel and should be brought to boiling. After having

collected 30 ml of distillate, 30 ml of 12 % HCl needs to be added in the distilling flask, and thus proceeding until 360 ml of distillate may be collected, this amount being certainly sufficient to have all the formed furfural passed into the distillate. (Generally, all the furfural is contained in the first 300 ml of distillate; however until furfural is present, a drop of distillate will give a pink color when coming into contact on filter paper with a drop of aniline reagent). 40 ml of the phloroglucin solution should be added to the distillate, then the volume of the liquid needs to be made up to 400 ml with 12% HCl. It may soon turn greenish-black and furfural-phloroglucide precipitates.

After 16 hours of decanting it should be tested whether all furfural has precipitated, by adding a drop of aniline: if pink color is obtained (presence of furfural) more phloroglucide must be added. The precipitate should be filtered through a filtering crucible with fritted disk of coarse porosity 11 G3 (or 11 G4). Care being taken that the filter may be always filled with liquid. The precipitate should be washed with 150 ml of distilled water, needs to be dried in oven at 100-150 ^{o}C for 6 hours, placed into a desiccator until it is cooled and then weighed.

4.3.2 Calculation of the results

The content of pentosans in the sample may be calculated from the weight of furfural - phloroglucide (a) on the basis of the following formula:

When the weight of phloroglucide is under 0.03 g:

Furfural = (a + 0.0052 + 0.0020) × 0.5170

Pentoses = (a + 0.0052 + 0.0020) × 1.0170

Pentosans = (a + 0.0052 + 0.0020) × 0.8949

If phloroglucide weight is between 0.03 g and 0.30 g:

Furfural = (a + 0.0052 + 0.0020) × 0.5185

Pentoses = (a + 0.0052 + 0.0020) × 1.0075

Pentosans = (a + 0.0052 + 0.0020) × 0.8866

Over 0.3 g

Furfural = (a + 0.0052 + 0.0020) × 0.5180

Pentoses = (a + 0.0052 + 0.0020) × 1.0026

Pentosans = (a + 0.0052 + 0.0020) × 0.8824

The content in percentage may be figured from the pentosans content in the sample, by the following formula:

$$\% \text{ pentosans} = \frac{\text{Weight of furfural phloroglucide} + 0.0072 \times 100 \times 0.8866}{\text{Weight of bone dry wood}}$$

NOTE: The value of pentosans may also be expressed as content of furfural (furfural deriving from hydrolysis). In such a case the possible errors deriving from presence of methyl-pentosans are lowered.

4.4 METHODOLOGY TO STUDY THE FIBER AND PULP CHARACTERS

During the last few decades, bamboo has become a major source of raw material for the Indian Pulp and Paper industry. The industry is presently facing problems of non-availability of suitable fibrous raw materials in adequate quantity to meet its requirements. The supply of traditional bamboo species for pulp making has been dwindling in recent years. Still bamboo accounts for sixty percent of the fibrous raw material requirements of the industry. With the gradual shortage of such raw materials, the pulp industries are forced to look for alternative stock (Shanmughaval and Francis 1996). Hence a methodology to study the fiber and pulp characters of the soft and hard woods is described herein.

4.4.1 Sample Preparation

The wood to be analyzed should be reduced by means of an electrical saw. The sawdust needs to be sieved sequentially through a 65 mesh and a 200-mesh screen. The material retained during the second sieving is "average wood" and should be used for the chemical analysis.

Bamboo (*Bambusa bambos*, *Dendrocalamus strictus*), Eucalyptus (*Eucalyptus tereticornis*), Watle (*Acacia decurrens*), Dadup (*Erythrina suberosa*) and Karuvelam (*Acacia arabica*) are used as raw material in the pulp industries. To study the pulp and paper characteristics of screened chips, at a density of 224, seventy six kg/m^3 should be collected from KMW HH 300 Chipper in case of wood and Sumner chipper in case of bamboo. They should be pulped individually in the laboratory series digester heated with indirect steam. The digester may be initially heated to a temperature of 80°C, upon which time oven-dried chips equivalent to 2000g would be charged with chemicals. The cooking should be done to get two values of kappa number. The H-factor should be maintained

at 1300. The pulping can be regulated by the H-factor, which represents time and temperature within a single variable. This concept can be applied to achieve similar pulp qualities inspite of variations due to unforeseen reasons in temperatures (or) duration of cooking. The cooking conditions should be maintained at 19-12% active alkali (as Na_2O) 25%, sulphidity, 1:3 liquor to chip ratio and 90 minutes to raise the temperature to 170°C.

After cooking the chips should be discharged, thoroughly washed, defiberized and then screened. The screened pulps would be pressed to remove excess water, shredded, weighed and then sampled to determine moisture content. The pulp yield and screened pulp kappa number should be determined, and physical strength properties should be studied in the unbleached pulp. The bleaching experiments should be carried out for the pulps using CEH sequence (successive stages of chlorination, alkaline extraction, hypo chlorination). The bleached pulps then refined in a valley beater to different freeness values and hand sheets should be made to determine the strength properties after conditioning the sheet at 23 ± 1 °C and 50 ± 1 % relative humidity. All the sheets should be tested according to scan test methods. The black liquor obtained in each case should be analyzed for total solids, inorganic organic ratio, acid soluble in- organics, the presence of sodium salts (Na_2O), free alkali, swelling volume ratio (SVR), calorific value and viscosity at different concentrations (Kueppen and Sitzman 1954; Palmer and Gibbs, 1967; Rys, 1949 and Singh and Sharma 1976).

4.4.2 Conclusions

Based on the above methodology our study revealed that,

1. While, a mixed cook is made, a minimum of 19% alkali is required to get a pulp, having a kappa number of 27±2.
2. A minimum yield of 44% can be obtained. Based on the yield percentage, if stationary digester is charged with 20 t BD chips and alkali of 18-19% keeping other parameters constant, the output would be 8.7 - 9.0 t of pulp.
3. If Karuvelam and wattle are used in excess, the same may bring down the burst factor in Kraft papers.

4. The pulp requires only 10% chlorine for bleaching to develop a brightness of 78%.
5. The black liquor of bamboo and dadup will help in the mobility of concentrated black liquor.
6. The swelling volume ratio (SVR) of dadup and wattle are good, having more than 40 ml/g. It shows that the fluidity and burning characteristics of black liquor are good if dadup and wattle are used more.
7. In all the cases, the chlorine consumption for bleaching is 9-10%. The shrinkage is more in the case of bamboo at 14%. In the case of dadup, the shrinkage is only 4%. The rest is ranging from 6-7%.
8. The mobility of the black liquor of bamboo and dadup is good since the viscosity is low when compared to others.
9. The swelling volume ratio (SVR) of all the materials is more than 25 ml/gm.

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5

EVALUATING THE RESULTS OF AGRO FORESTRY RESEARCH

5.1 INTRODUCTION

Agro forestry field experiments are considerably more complex than research confined to annual crops. It follows that evaluation in agro forestry is also a complex task. Agro forestry systems yield many products and services, all with different values and functions, and all harvested at different times over periods as long as several years. Moreover, some of the benefits of agro forestry are intangible and difficult to value, such as shade trees or live fences around homesteads.

The methods of evaluation must always be based on the objectives of the experiment. For example, the methods used to evaluate multipurpose-tree species grown on contour bunds for fodder production will be quite different from the methods used to compare different improved-fallow systems, or even from the methods used to compare the same tree species grown on bunds but for erosion control.

Researcher-managed trials are normally evaluated only in biological terms. Limited economic assessment might be possible, but research plots are usually not large enough to measure factors such as labor requirements for planting, weeding and harvesting. There can be no social

evaluation-assessing the responses of farmers, if farmers are not involved in managing the experiment.

Because agro forestry experiments have so many different objectives, it is not possible to define one, or even a few, methods of evaluation. Instead we shall discuss four areas which in our experience often cause problems:

- Choosing suitable samples for measurement from experimental plots
- Converting measurements to a per-hectare basis
- Evaluating multiple outputs
- Extending evaluations over many cropping seasons.

5.2 CHOOSING SUITABLE SAMPLES

On experimental plots that contain only crops, the border and edge effects must be considered, but otherwise it is not difficult to choose a sample area from which to measure yield.

On a typical agro forestry plot, with both trees and crops, difficulties arise from the fact that all parts of the plot are no longer equivalent. We would expect the crop adjacent to or under the trees to be different either better or worse from the crop outside the tree's influence. Some examples of measurements to assess these differences are:

- In a hedgerow-intercropping system, measuring the crop rows in the center of the alley and the row next to the hedge to determine whether tree/crop interface effects are positive or negative
- Measuring the crop in concentric circles of increasing radius to determine the distance over which scattered trees affect crop yields
- Measuring crop rows above and below terrace risers to assess the effects of trees in different position on contour terraces
- Measuring crop rows on the windward and leeward sides of trees to determine any shelter effects.

In many experiments, different parts of each plot must be measured separately. In hedgerow intercropping, for example, the evaluation of tree/crop-interface effects is based on comparing the crops adjacent to hedges with the crops in the middle of the alleys and then comparing plots with different treatments in terms of these differences.

There is no reason to convert such differences to a per hectare basis.

Similarly, the pattern of crop yields at different distances from a tree can be analyzed on individual plots and then compared between plots with different treatments. Figure 5.1 illustrates yield levels 1, 2, 3 and 4 meters from a tree on a single plot. To facilitate comparison with results from other plots, these data can be summarized as the difference between the two extreme values (0.38 kg/m^2 in this example) or as the four points (0.12kg/m^2/m) or as the slope of a regression line fitted to the four points (0.12 kg/m^3) (Huxley et al., 1989).

Two problems may arise. First, the researcher may fail to ensure that the crop area measured represents the system as a whole. For instance, measuring only the centre rows in a hedgerow-intercropping system will give a misleading picture of the production of the entire system.

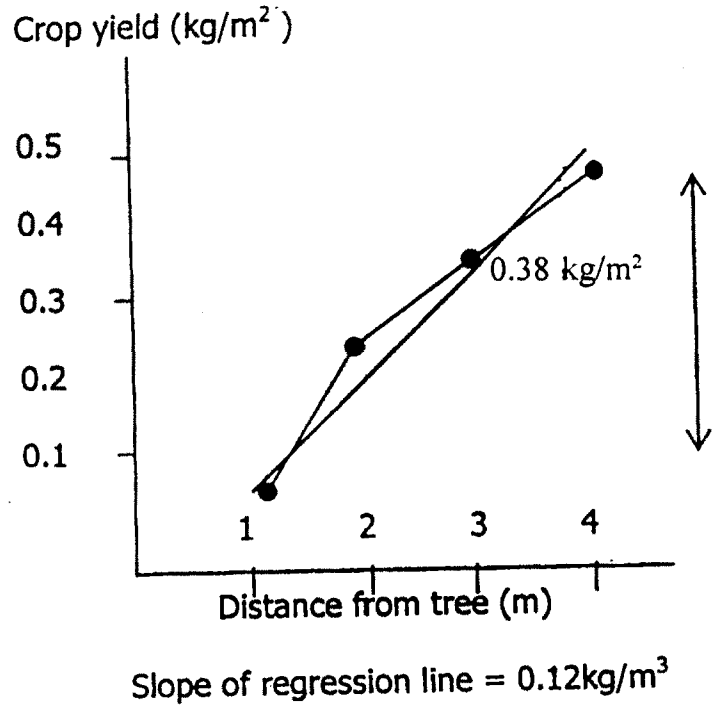

Figure 5.1. Crop yields at different distances from a tree. The fitted regression line has a slope of 0.12/m^3.

Similarly, measuring crop yield under a tree and away from the tree and then averaging these two numbers will only give a correct estimate of production if the area under trees accounts for 50% of the land. If trees occupy a different proportion, then the two measurements must be weighed accordingly. The easiest way to avoid this problem is to choose a sample area that can be repeated across a field to produce a complete picture of the system.

Figure 5.2 shows a hedgerow-intercropping experiment with hedges 4 meters apart and five rows of maize in each alley. Possible harvest areas are shown as a, b, c and d. Yield measurements from c or d would represent the system as a whole, although in d the harvest area for the crop is twice that for the hedge. Measurements from a or b would not give representative results as a has two middle rows and b has none.

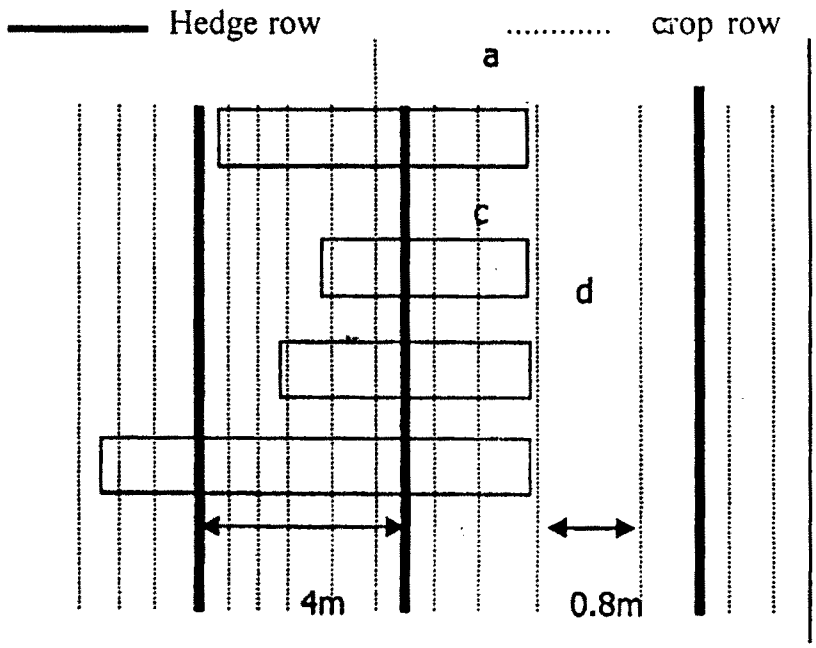

Figure 5.2. Hedgerow-intercropping plot: c and d are correct sample areas for measuring crop yields, but a and b are incorrect.

5.3 CONVERTING TO A PER-HECTARE BASIS

Comparisons between different agro forestry systems require calculations of yield on a per-hectare basis. For example, crop production per hectare is evaluated to compare a system of scattered trees on

cropland with sole cropping or to compare hedgerow-intercropping systems using different tree species.

Researchers often make mistakes when converting yields from sample areas to yields per hectare. The problem is usually due to a miscalculation of the sample plot area, leaving out the area occupied by trees.

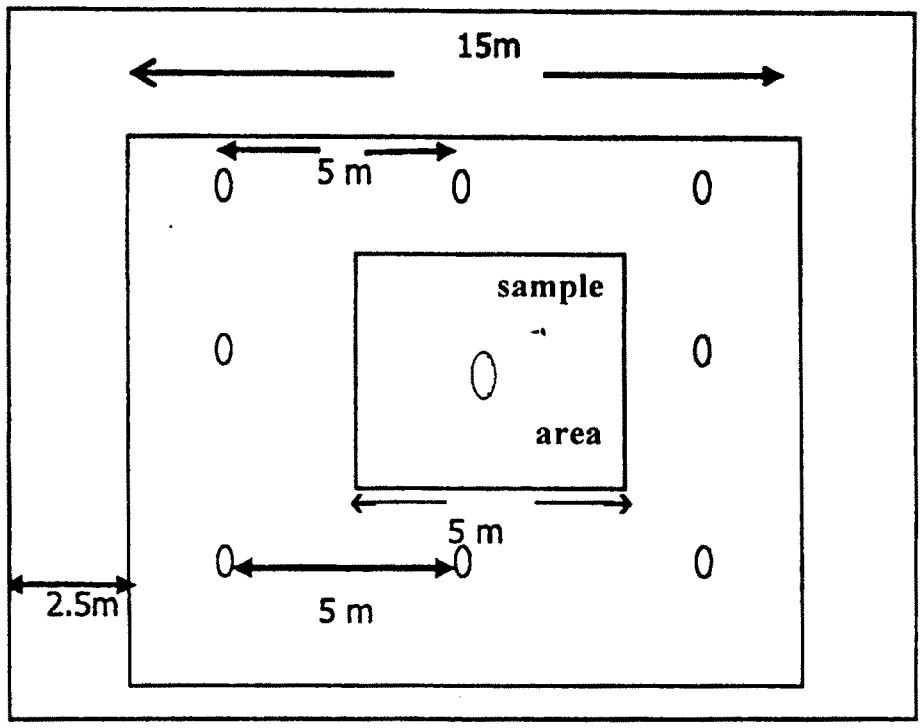

Figure 5.3 Sample area for measuring crops in an agro forestry system with trees scattered on crop land at 5 meters interval. Any other sample area would not represent the crop yield for the system.

Again, the easiest way to get this right is to think of sample areas that can be repeated across the field. Figure 5.3 shows the correct sample areas for two hedgerow-intercropping designs plus control plots. In a, b and c, the harvest area is 4 × 8 meters = 32 m^2. In a, only 4 rows of maize are measured. As the between row spacing is 0.8 meters, it is tempting to take the width as 4 × 0.8 meters = 3.2 meters, and the plot area as 8 × 3.2 meters = 25.6 m^2. This would be incorrect because the area occupied by the hedge is ignored. Using this area would result in a per-hectare yield inflated by 25%.

Similarly, when calculating tree yields per hectare the area occupied by the crop must be taken into account. If 8 meters of hedge are harvested (Fig 5.4), then the appropriate harvest area is again 32 m^2. Conversion to a per-hectare yield requires multiplying the yield from 8 meters of hedge by 10000/32 (Willey,1985).

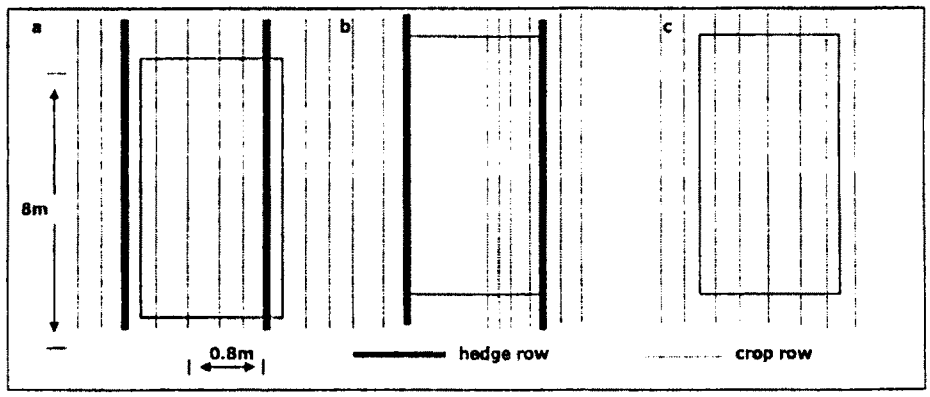

Figure 5.4. Sample areas of 4×8 metres for (a) a hedgerow-intercropping plot where the hedge replaces a crop row, (b) a hedgerow-intercropping plot where the hedge does not replace a crop row, and (c) a sole crop plot.

5.4 EVALUATING MULTIPLE OUTPUTS

In some agro forestry systems there is only one major output, such as crop yield in a hedgerow-intercropping system designed exclusively to enhance soil conservation or fertility. In such a situation, the evaluation techniques used in agronomy trials are appropriate. One technique is based on analyzing the response to fertilizer under sole cropping and under agro forestry and estimating the effect of the agro forestry system in terms of the equivalent added fertilizer (Fig 5.5).

More common is the situation in which there are two or more useful outputs-from the tree and crop components and each must be assessed. Even if the crop component is ignored, there may be several variables related to the trees (Table 5.1). No single index can integrate tree outputs (timber, fuel wood, fodder, mulch) and crop yields adequately to allow the ranking of agro forestry systems or components.

Instead, an evaluation should help explain why species differ for instance, if trees compete differently with adjacent crops because of different rooting patterns so that an appropriate species can be selected for a particular purpose. This is illustrated by the preliminary results of

Table 5.1. Major Criteria for evaluating multipurpose trees for agro forestry

Criterion	Agroforestry Technology				
	Hedgerow Intercropp-ing	Mixed Inter-cropping	Fodder Lots	Boundary Plantings	Improved Fallows
Foliar biomass (t)	×	×	×	—	×
Woody biomass (t)	×	×	—	×	×
Nutrient or protein yield (kg)	×	×	×	—	×
Depression/increase in crop yield (%)	×	×	×	×	×
Quality of follar biomass (C.N., N:lignin/ phenolics)	×	×	—	—	×
Quality of woody biomass (specific gravity)	—	×	—	×	×
Pests and disceases	×	×	×	×	×
Growth form (shape)	—	×	—	×	—
Longevity after coppicing	×	—	×	—	×

an upper storey tree species screening trial in Uganda (Table 5.2). In this case, the species that ranked high in terms of height and diameter growth were also the most competitive with crops. Similarly, species that produced wide crowns tended to suppress crop yield.

Another complex set of agro forestry systems involves growing trees and grass in combination on contour bunds for fodder production. Different systems are compared in terms of production on the bunds including such measures as tree and grass production, total biomass and total protein produced—and also in terms of production of neighbouring crops (Huxley et al 1989).

Mead (1986) describes the value of bivariate analysis in intercropping research. This technique could also be applied to agro forestry trials that have two key outputs. It involves looking at the joint variation of the two outputs, as depicted in simplified form in Figure

5.6. This can be extended to more than two variables, but interpretation becomes difficult, as graphs are hard to draw.

An obvious approach to the problem of multiple outputs is to produce an index that 'synthesizes' them into a single value. Researchers sometimes do this by assigning weights to each characteristic, reflecting an assessment of their relative importance, and averaging them. This approach can be effective if the weights are based on clear objectives, but there are pitfalls. In effect, the assignment of weights determines the results: weights can be chosen to prove almost anything!

Even if weights are based on a well-defined criterion, producing an index still reduces the information presented and can give a misleadingly simple picture. However, two approaches to indexing have proven valuable—the land equivalent ratio (LER) and economic indices.

Consider a hedgerow-intercropping system producing an annual crop plus fodder from the hedges. If both of these products are equally valuable, the system can be compared with a system in which land is divided between sole blocks of annual crops and of fodder trees in a suitable proportion. The land equivalent ratio is a convenient method to compare the biological productivity of these two arrangements by combining the two types of yield. It is defined as the land area in the sole system that would be required to produce the same yields as one hectare of hedgerow intercropping. It is calculated as follows:

$$LER = Ci/Cs + Ti/Ts.$$

Here Ci and Ti are crop and tree yields under hedgerow intercropping and Cs and Ts are yields in the sole system (Table 5.3).

The calculation of the land equivalent ratio should be based on the most important products of the systems. These might be grain yield of annual crop plus fodder yield of trees, or the total biomass of crop (grain + stover) and of trees (fodder + wood). By contrast, if fodder is the main product, it might be appropriate to base land equivalent ratios on protein yield.

Various methods have been proposed for calculating land equivalent ratios for even more complex systems, for example, when there are several crops per year (Balasubramaniam and Sekayange, 1990) or when the agro forestry system does not produce tree and crop components in

the desired proportions (Willey, 1985). However, in such situations the land equivalent ratio has limited practical value.

The real usefulness of land equivalent ratios lies in situations where sole stands of tree and crop components are viable alternatives. If the farmer would not grow a block of trees for fodder, for whatever reason, then a land equivalent ratio that compares an agro forestry system with this alternative is not particularly useful.

Land equivalent ratios may also be calculated to assess the fodder yields of different combinations of grass and shrubs on bunds. However, it is not easy to include an assessment of the adjacent crop in this analysis since a sole-crop system—with the crop on the bund—is not an interesting alternative.

It is worth noting that the land equivalent ratio is only a relative measure: it does not reveal the magnitude of fields. Also, two land equivalent ratios are only comparable if they are both based on the same sole crop yields.

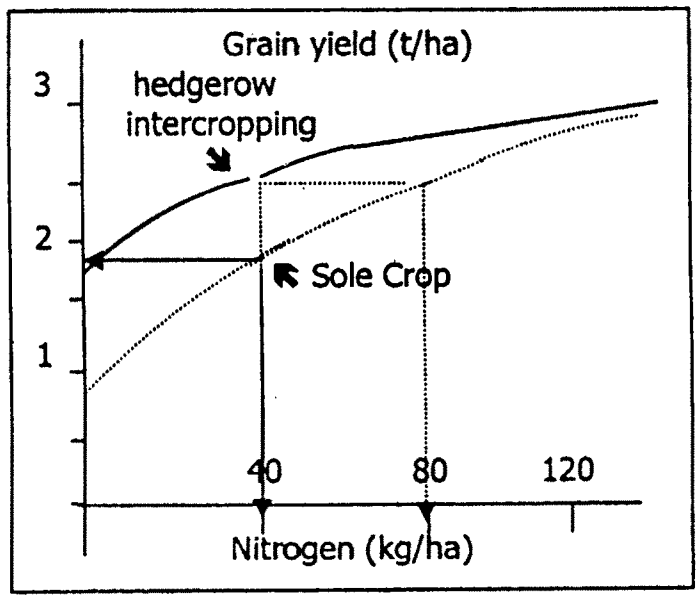

Figure 5.5. Comparison of crop response to nitrogen fertilization between sole crops and under hedgerow intercropping.

For instance, a hedgerow-intercropping system that combines *Leucaena leucocephala* with grass might have a land equivalent ratio of 1:1 compared with a system of Leucaena and grass planted separately,

whereas a system combining *Gliricidia sepium* with grass might have a land equivalent ratio of 1:3 compared with a 'system of separate Gliricidia and grass. However, we can not conclude that the Gliricidia /grass mixture is more productive than the Leucaena /grass system. The Gliricidia mixture may have a higher land equivalent ratio not because it is more productive than the Leucaena mixture, but because the separate Gliricidia and grass system, with which it is compared, is less productive than the separate Leucaena and grass system.

5.5 ECONOMIC EVALUATION

At first sight, evaluation in economic terms appears straightforward. We simply calculate each output per hectare, weigh it by its value, add up the values of all the outputs, and obtain a total value for the system. However, there are difficulties.

Table 5.2 Growth characteristics of seven upper storey tree species 13 months after planting and effects on adjacent bean crop.

Tree Species	Height (m)	Root Collar Diameter (cm)	Average Row yield of Bean Relative to Sole Crop (%)
Alnus acuminata	1.24 (7)	3.2 (6)	146 (1)
Casuarina equisetifolla	2.40 (3)	3.8 (5)	100 (4)
Cordia abyssinica	3.62 (2)	9.3 (2)	46 (6)
Cupressus lusitanica	1.61 (6)	3.2 (6)	114 (2)
Maesopsis eminii	2.09 (5)	5.3 (3)	96 (5)
Markhamia lutea	2.26 (4)	3.9 (4)	107 (3)
Melia azedarach	4.36 (1)	11.1 (1)	46 (6)

It is simplest to base calculations of economic value on price, but prices may vary both seasonally and in the long term. Even worse, the price of an output may be difficult to determine or may not even be relevant if there is no cash market for the product. Further complications arise from the different time periods required to produce different outputs-it takes longer to produce a building pole than a cereal crop. The costs of inputs also vary.

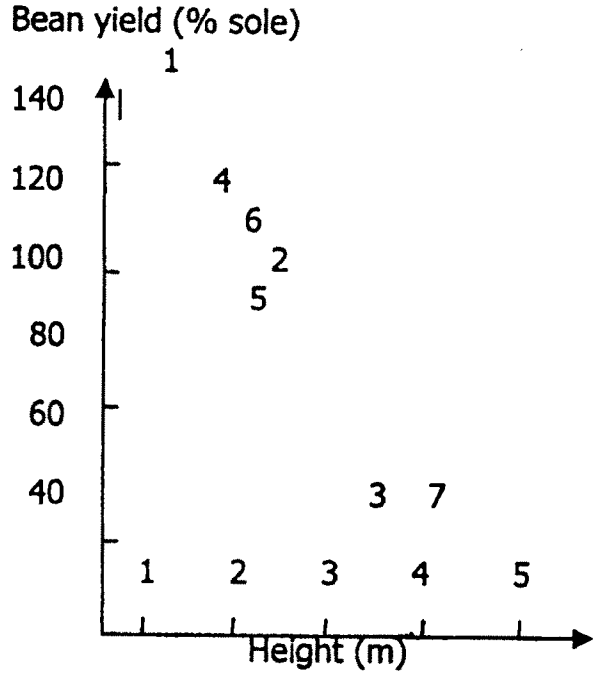

Figure 5.6. Tree heights 13 months after planting and yield of adjacent bean crop, as percent of sole crop, for the seven multipurpose-tree species listed in Table 5.2.

5.6 EVALUATING OVER MANY SEASONS

It is essential to evaluate agro forestry systems over a sufficiently long period, typically for a minimum of five years. There are two main reasons for this. First, many of the potential benefits of agro forestry are long term. Obvious examples are soil-erosion control and fertility maintenance. Whilst it might be possible to measure some of these benefits directly over a few seasons, their impact on crop productivity must be monitored for a longer period. Trends can be depicted simply by plotting outputs from different systems over time (upper graph in Figure 5.7).

The second reason is the variation in weather that inevitably occurs from year to year. The relative performance of different agro forestry systems can be quite different under different weather conditions. A system that performs well when there is adequate rainfall might perform poorly in seasons of water shortage.

It is difficult to give a rule for the number of growing seasons necessary to evaluate different systems, but the evaluation period must include the range of climatic conditions usual for the site. The graphs

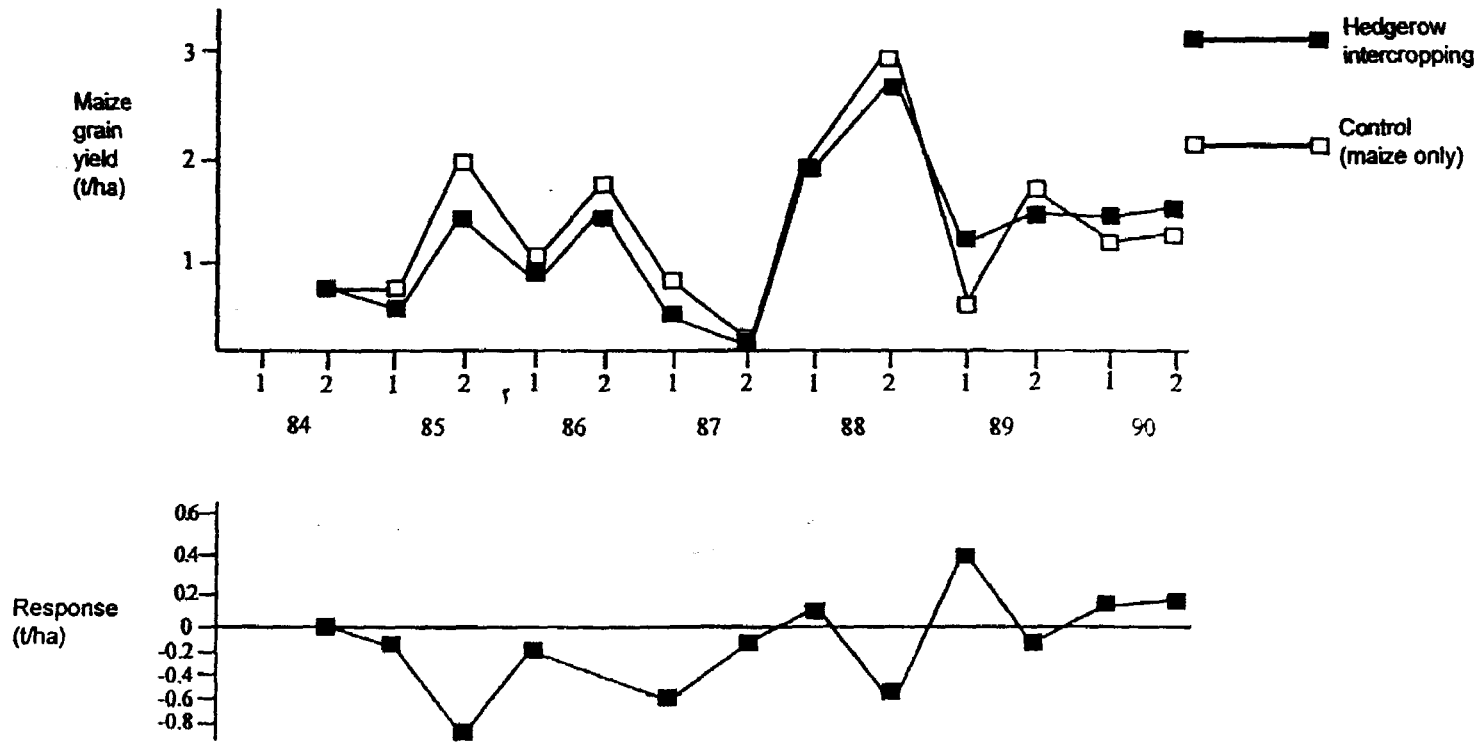

Figure 5.7, Upper graph shows average maize yields at Machakos, Kenya, under hedgerow intercropping and sole cropping during 14 growing seasons, from 1984 to 1990. Lower graph shows the response of maize yield to hedgerow intercropping. Values below zero indicate that crop yields were lower under hedgerow intercropping than sole cropping, whereas values above zero indicate that yields were higher under hedgerow intercropping (Mugendi and Muthoka,1991).

shown in Figure 5.7, will change according to variations in the weather, but trends will become apparent over time.

Some seasonal variation can be removed by plotting responses-the differences from a standard control—as shown by the lower graph in Figure 5.7. However, such calculations do not give absolute values, which are important when considering sustainability. Plotting responses may also obscure a pattern in which one system does well in good years and another does well in poor years.

When a particular climatic event has an important effect on trees or crops, we can calculate the likelihood of it happening again using long-term meteorological records. Suppose tree establishment is poor because of a three-week dry spell after transplanting, the chance that such a dry spell will occur in any year can be calculated simply by looking through climatic records. If such a spell occurred only twice in the past 40 years, we can estimate the risk as 2/40 = 5%, probably an acceptable rate. If the risk is 75%, then any agro forestry system that would fail in such a dry spell will not be viable.

Table 5.3. Land equivalent ratio of Leucacena hedges producing fodder (dry weight) with a maize intercrop

Sole Maize	Sole Leucacena	Hedgerow Intercropping
4 t/ha grain	6 t/ha fodder	3.2 t/ha grain + 2.4 t/ha fodder

$$\text{The land equivalent ratio of the system} = \frac{3.2 + 2.4}{4.0 + 6.0} = 1.2$$

This means that the productivity of 1 hectare under hedgerow intercropping is equivalent to that of 1.2 hectares under the sole system. In other words, hedgerow intercropping is 20% productive than the sole system.

However, differences in weather could still affect the growth of the fallows themselves. Thus, if other factors are under consideration in addition to length of fallow-tree species for example—then the entire experiment needs to be repeated starting in different years. If the design does not account for the effects of weather in different years, then the best that can be done is to look at responses, comparing various

treatments with a control. Even so, the confounding effect of weather cannot be eliminated completely for two reasons; the magnitude of responses varies according to the weather, and the actual effects of weather may not be proportional to the way weather is measured normally based on the amount of rainfall.

During fallow periods, land is out of production. Particularly in areas where land is scarce, it is important to compare different fallow systems on the basis of average annual production taking both the fallow and cropping periods into account.

The situation is further complicated if the tree fallows yield some economic products such as fodder, fuel wood or timber. These products must also be considered in an overall assessment of the system.

Under diverse and rapidly changing conditions--particularly socio-economic conditions—no one evaluation method can give all the answers. An agro forestry system that works well in one location may not be appropriate in another, and a system that works well today may not be appropriate tomorrow. In addition, if systems are judged purely according to short-term results, important sustainability aspects may be overlooked (Mugendi and Muthoka, Rao and Roger, 1990).

A comprehensive evaluation must consider the economic and social aspects of an agro forestry system, as well as the biological. Such an evaluation requires accurate long-term data. Experiments should be conducted over a minimum of five years even longer if possible. A shorter experiment not only misses out the long-term potential of an agro forestry system, but also risks inaccurate conclusions due to short-term vagaries of climate.

Finally, the difficult task of integrating the effects of soil, climate and various plant-management options calls for the development of appropriate software development and computerized models. Models could help assess resource capture and utilization, nutrient cycling, the growth and productivity of components, and long-term sustainability. This is an area where considerable work is yet to be done.

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6

SOCIAL FORESTRY

6.1 INTRODUCTION

Social forestry programs in India have grown in importance and scale and now continue to be a major element in India's overall program of rural development. From modest beginnings over a decade ago, there has been an almost exponential growth in the human and financial resources devoted in social forestry.

The term social forestry is difficult to define precisely, but is generally understood to mean tree-growing (including associated products, e.g., bamboo, grasses, legumes) for the purpose of rural development. As social forestry has a rural development focus and is heavily dependent on the active participation of people, it is also known as "forestry for local community development" or "participatory forestry" (FAO, 1985, 1986). Although wide ranges of activities are included in social forestry, five main components can be distinguished in India. With variation, they are:

1. Farm forestry (tree growing on private land),
2. Farmer leasehold or tree patta,
3. Village woodlots or community forestry,
4. Strip plantations alongside roads, canals, railways, etc., and

5. Reforestation or rehabilitation of degraded forest areas.

Social forestry programs usually include one or more of these components. There are also distinctions between and within these components depending on who owns the land on which the trees are being planted (e.g.,. private farmers, private industries, municipalities, forest departments, revenue departments, etc.) or who is responsible for the planting (e.g. farmers, villages, cooperative, voluntary agencies, rural development departments, schools, etc.).

Although these distinctions are sometimes blurred, all forms of social forestry are differentiated from commercial or territorial forestry by the involvement of the rural population in decision-making, management and as beneficiaries.

Farm forestry is tree planting undertaken by individual households on their own land or land they have rented from others. Tree seedlings may be planted in blocks (small plantations), on field boundaries, or around homesteads. They may be intermixed with agricultural crops in several forms of agroforestry, or they may be planted alone on either agricultural land or uncultivable wastelands. Farmer leasehold or tree patta denotes a kind of farm forestry in which poor farmers or landless labourers are given leases to tracts of public land on which, with varying degrees of public support, they are constrained to grow trees. Village woodlots are small plantations on communal or government land, operated by or on behalf of the village, for the benefit of the village as a whole, although there may be special arrangements, which provide preferential treatment to the under-privileged. Strip plantations are relatively narrow areas along the sides of roads, canals, railways, and rivers, established by the Government (usually the Forestry Department) with the intention of providing the benefits of forest products to local people and to serve as demonstration areas. The reforestation or rehabilitation of degraded forest refers to large plantations on public lands, which have been degraded, and which are often in environmentally critical areas. Such plantations may or may not be considered a form of social forestry depending on whether or not there is significant involvement of local communities (FAO, 1985).

The objectives of social forestry necessarily differ by components.

While all social forestry aims to increase tree production and reduce environmental degradation, the nature of the product, the type of management, and the distribution of benefits depend on the type of social forestry involved. Farm forestry is designed to help rural households better meet their own needs, whether through the direct production of fuel wood, fodder, and poles for their own use or through the production of a commercially marketable crop of poles or pulpwood. Tree patta forestry is similarly designed to increase the incomes of poor households through the sale of forest products and at the same time to help satisfy their need for fuel wood and fodder (NWDB, 1989a). Village woodlots are intended to provide tree products, particularly fuel wood and fodder, for the community as well as (in many cases) incomes to the local village panchayat. Strip plantations and reforestation are designed to provide local communities with some of their fuel wood and fodder needs and to conserve and improve the environment. To a varying degree, each of these components has features, which deliberately target benefits towards the poorest and most under-privileged sections of society, including rural women who are frequently those hardest hit by the growing scarcity to tree products. However, these poverty-alleviation objectives and those related to production are often confused and this contributes to the widespread controversy surrounding the social, economic and environmental effects of social forestry (FAO, 1986).

The massive social forestry programs being carried out in India are, at present, spearheaded by the National Wastelands Development Board specially created by the Prime Minister. While the principle implementing agencies for these programs in each state are the Forest Departments other government departments and private and voluntary agencies, are increasingly being mobilized to meet national objectives. State Forest Departments have typically introduced new organizational structures to plan and implement social forestry activities and have appointed separate staff in the field and at headquarters. For forestry departments as much as for other departments and agencies, social forestry represents a departure from traditional activities and styles of working (FAO, 1986).

6.2 GUIDELINES FOR SOCIAL FORESTRY PROGRAM

Community forestry programs are based upon growing trees on

public or community land as opposed to private farms. The degree of local participation in planting and looking after the trees varies. What all community programs have in common, is that they are intended to provide benefits, which are shared by the community as a whole.

The most common type of community-forestry programs is that in which the forest department takes on the responsibility for carrying out the planting. The community provides inputs such as fertilizers and seedlings without any outlay. The engagement of the local community in the implementation of the schemes of this type is largely passive and is normally restricted to the provision of hired labor for planting and an agreement to cooperate in protecting the plantation.

Other programs rely on a much higher level of community participation and control. They are generally designed to use land, which is under direct community ownership; (or) they can take place on state lands, which have been specially designated for community control. Community itself takes the main responsibility for planting and looking after the trees and the role of the promoting agency is primarily a catalytic one. Community programs can use both commercial and non-commercial incentives as a way of stimulating local participation. In all cases, the key to success lies in persuading local people that the program is in their interests such that the benefits they are promised are securely guaranteed.

6.2.1 Degree of local participation

As discussed earlier, the aim of community forestry programs are to regenerate the degraded forests and barren lands.

(a) Local institutions

Community tree growing programs are crucially dependent upon the active collaboration of village councils; community groups (or) other local institutions. Program planning must therefore be based upon a clear appreciation of actual role, such organizations play in local affairs, and their potential for realizing or thwarting the aims of the program. The village community groups should be trained or giving proper instructions, about the growing of bamboo in the barren land by the specialists in the field. While selecting the village community groups, preference will be given only to the educated unemployed youth.

(b) Land allocation

Maximum 25 ha area of degraded/barren forestland is to be

allocated at a time to each participating village group. In future, more land can be allocated if the work of the participating village committee is found encouraging.

(c) Procedure of working

After collaborative micro planning a need-based management plan will be drawn up. The forest department will assist the village committee to establish joint protection and management systems.

(d) Requirements/Rule of working

Order requires participating village committees to project the allocated land against non-forestry use, encroachments, grazing, illicit-felling and wildlife. Land in no case is to be allocated to individuals and ownership of the land shall remain with the Government. It is also required to execute an agreement bond-between forest officials and the participating village committee.

(e) Resource sharing

Entire bamboos obtained from community forestry programs will go to the members of the participating village committee. At the time of harvest prescribed in the management plan, after deducting the government expenditure, 60 percent share of net income will go to the members of the participating village committee and 40 percent share to the state exchequer. Participating village committee will again invest at least 50 per cent of this income in plantation activities.

(f) Monitoring of works

A supervisory committee is to be constituted to monitor the development, protection and management works of the community forestry. Members of the committee will include respective district forest officer, a range officer, and a representative of village committee members.

6.2.2 Limitations

a) The problem of land- use conflicts

Obtaining the necessary land for tree growing is undoubtedly one of the major stumbling blocks in programs of this type. Community land is frequently scarce, or is being used for a variety of other purposes. Agreement to dedicate it to tree growing can be very difficult to achieve.

b) Lack of identity of interests

Few communities have a genuine identity of interests among all

their members. Practical experience has shown that this can cause a number of severe problems with community programs, where communities are rigidly stratified along social, economic or religious lines, the barriers to communal action can be partially difficult to over come.

6.3 SCOPE FOR COMMUNITY FORESTRY

The Community forestry programs, with their needs for compromise and reconciliation of opposing interests, means that they will always require a great deal of careful preparation and negotiation. This demands a high level of trust and co-operation between the community, and the promoting agency, which can, itself take a long time to create.

6.4 MONITORING AND EVALUATION

Despite the magnitude of the social forestry programs in India, there is little reliable information available to policy makers and program managers regarding the progress and effects of the program (NWDB, 1989b). This is perhaps, because of the novelty of the approach and the rapid and recent expansion. The widespread lack of effective information systems has hampered management and policy makers in improving the design and implementation of their programs. The scarcity of reliable information has also led to controversies and debates fueled more by impressions, isolated field visits and pre-determined opinions than by objective empirical information.

For these reasons, the Government of India and most of the State Governments and other agencies involved in promoting social forestry have placed a high priority on developing an effective monitoring and evaluations (M&E) system to serve both the State Government Departments and Agencies and the Central Government. To meet this need, most social forestry projects have made specific provision for the establishment of monitoring and evaluation units (MEUs), which are expected to collect and interpret information on all social forestry activities. In a number of states, such units have been set up and have commenced operations. In other states units are planned (FAO 1986).

The primary role of monitoring and evaluation is to improve program or project implementation so that the program's ultimate objectives can be met and/or periodically measure progress towards these objectives (Wagh and Rajput, 1991).

Monitoring can be regarded as an assessment of the efficiency with which the program is implemented-including measurement of the quantity and timing of input delivery and output produced. Monitoring is usually understood to include the tracking of both financial and physical activity through regular quantified reports. While detailed financial reporting and accounting systems are usually already in vogue for auditing purposes, systematic physical reporting and monitoring of the implementation process (both problems and progress) is not well developed. The relationships between financial expenditures and physical output are not usually studied and hence little is known about the unit costs of achievements or whether lower costs would have produced equivalent results (FAO 1986).

In contrast, evaluation can be construed as the assessment of the results of implementing the program. On going evaluation is a means of examining the most important direct effects of the program concurrently with this implementation. This form of evaluation, sometimes called beneficiary monitoring, is meant to serve as an extension of the monitoring system in the sense that its primary purpose is still to provide managers and policy makers with information about the individuals and communities affected which will allow program implementation to be improved (NCA, 1976).

Ex-post evaluation is differentiated from on going evaluation being conducted when a project or program is completed as a means of assessing its overall impact and achievements, This type of evaluation, while not inherently undesirable, is complex, has a rude appetite for data, and usually requires sophisticated analytical methodologies and considerable financial and computing resources (FAO, 1985,1986).

Since monitoring and on-going evaluation are closely related they can often profit from being functionally integrated. Hence, while monitoring lays stress on the reporting of project progress and constraints as a time bound aid to program management, it should be closely linked to evaluation when the later is used as a means of determining whether implementation is meeting its original objectives or producing unanticipated results which may affect (positively or negatively) the outcome of the program.

As widely recognized in India, a separate and specialized

monitoring and evaluation unit (MEU) is necessary to implement an effective M&E system. In order to maximize the MEU's direct usefulness to management and to the daily implementation of a social forestry program, it is recommended that, as is generally the practice, the unit be located within the implementing department or agency and report directly to top management. The duties and responsibilities of the MEU can be summarized as follows: (FAO, 1985, 1986),

(a) To establish, in cooperation with program management, clearly defined objectives and regrets for program implementation against which progress can be monitored ;

(b) To implement and operate a monitoring system, including the development and application of methodologies and procedures for the collection and analysis of information.

(c) To collect information to enable the periodic evaluation of progress and effects through existing administrative and accounting records, surveys and studies and to analyze, interpret and report the findings to management and, through them, to policy makers and other interested bodies;

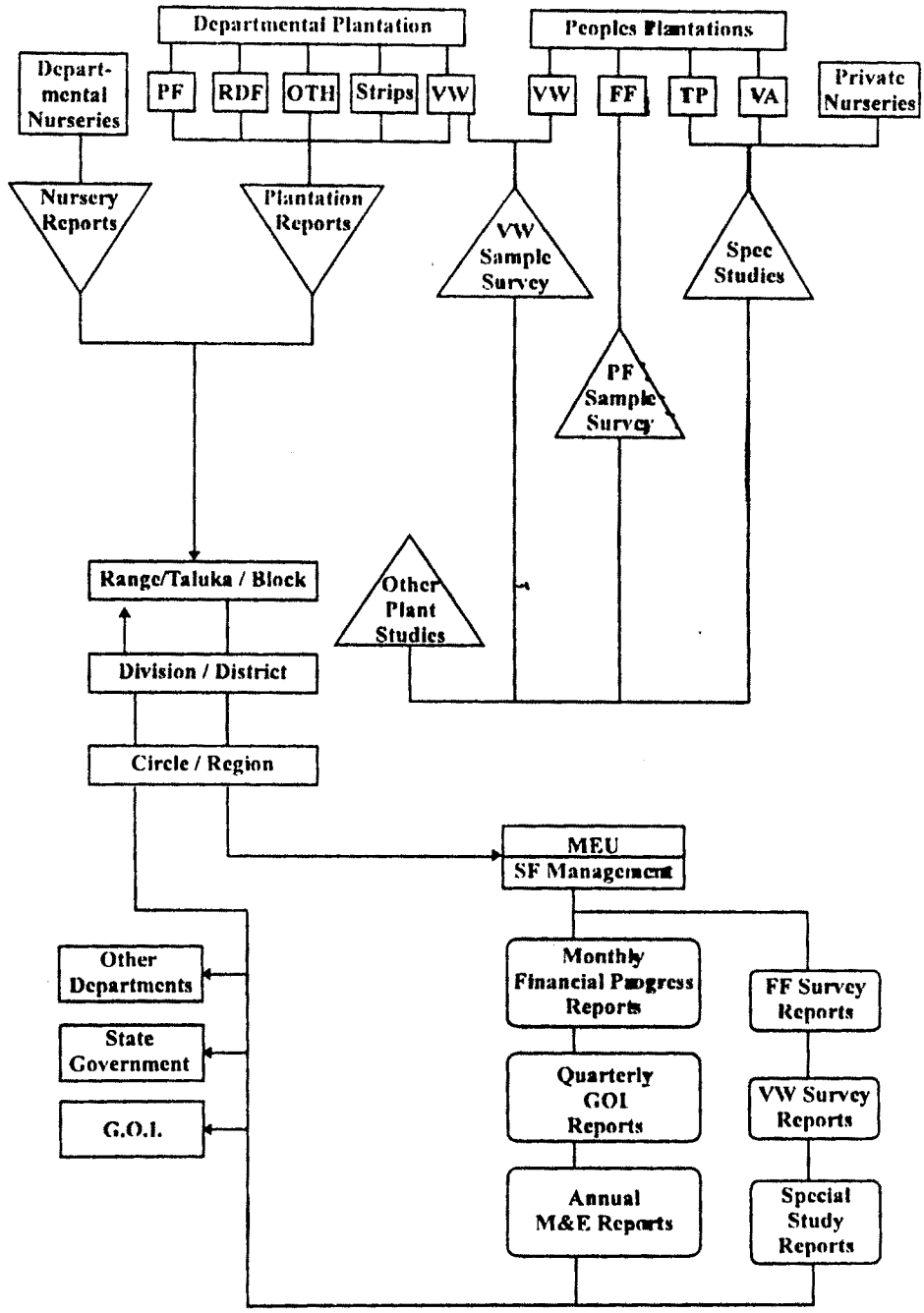
(d) To undertake on ad hoc basis, enquiries and studies in order to solve urgent problems for management; and

(e) To follow-up on the recommendations and results of monitoring and evaluation and assist in integrating them into future plans.

However, MEUs should not generally undertake investigations that are more properly classified as research studies, even though they may be relevant to program performance. For example, studies of the impact of different silvicultural regimes on water tables, of the agronomic and economic interactions of trees and crops, or of the impact of increasing fuel wood supplies on health and nutrition should all be considered as long term research studies outside the purview of an MEU. Not only are such studies long-term in that they have to be carried out over many years for the results to have some validity, but they are costly and technically complex and are, therefore, best carried out by research institutions.

6.5 AN OVERVIEW OF THE M & E SYSTEM

To aid understanding of the system as a whole, Figure 6.1,



NOTES: PF = Production Forestry, RDF = Rehabilitation of degraded Forests, Oth = Other, VW = Village Woodlots, FF = Farm Forestry, TP = Tree Patta, VA = Voluntary Agencies, Spec = Special, SF = Social Forestry, MEU = Monitoring and Evaluation Unit

Fig. 6.1 : Information Flow in the M&E System

provides an overview of the sources, flows, and destinations of M&E information. The top most part of this figure shows the main activities of a social forestry program. The categories of plantations are shown in Figure 6.1, which deals with progress reporting. Downward opening triangles denote monitoring information, derived from nursery registers and plantation journals, which is reported for all activities by social forestry field staff. Upward pointing triangles indicate data collected by the MEU through sample surveys and special studies which comprise a different, but important part of monitoring and evaluation. This part of the data collection system is primarily required for "People's Plantation" where departmental staffs are not directly responsible for planting activities and thus cannot be expected to report on them as part of their normal work.

The lower part of Figure 6.1, shows how the data obtained by the MEU after being transformed into usable information and summarized in reports, the most concrete output from monitoring and evaluation units, is disseminated to managers, policy-makers, and the field personnel responsible for implementation in order to provide feedback to improve performance.

In order to be truly useful, monitoring and evaluation must be undertaken in a thoroughly professional manner by specialists provided with adequate resources. This is only possible if the M & E unit is integrated with, used and directed by program management. Hence, it cannot be over-emphasized that management must fully understand the purpose of monitoring and evaluation and resist any temptation to regard M & E staff as an inspectorate or internal police force whose sole purpose is to criticize or report wrong doing. The first step by management in making this commitment is to ensure that the requisite funds and manpower are made available to the unit. Thereafter the M & E system will flourish in direct proportion to the extent to which management needs its products and gives focus to its enquiries. Monitoring and evaluation is an adjunct to improved management. Its primary justification is that, when done well, it can help social forestry programs attain the objective of helping rural people through tree husbandry.

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7

NURSERY TECHNOLOGY

7.1 INTRODUCTION

There remains little doubt if any about the need to promote reforestation in the developing world. Governments and peoples of developing tropical and subtropical nations worldwide are recognizing the ecological and economic value of maintaining and restoring their forested lands. Vast efforts and sums are being expended by governments, organizations and individuals throughout the tropics to protect existing forests and to reforest, afforest, or otherwise rehabilitate lands denuded of trees. Hundreds of millions of tree seedlings are being produced and planted annually across the tropics, resulting in the establishment of many square kilometers of new forests, or the integration of trees into the farming systems of millions of small land holders.

Unfortunately, the impacts of these enormous expenditures of human energy and scarce financial resources are being severely hampered by the use of antiquated, and in some cases, deleterious, methodologies and technologies. Many of the tree seedling production systems currently being used in the tropics are based on outdated technology, and these are the focus of this chapter. Nurseries are the cornerstones of nearly all reforestation success. Yet nurseries in the developing world nearly always depend upon labour-intensive seedling production methods that

require long time periods in the nursery which increase costs, hamper seedling transport and thus restrict large-scale tree seedling distribution and planting.

Tremendous opportunities exist for the improvement of tree seedling production systems to provide greater numbers of more vigorous seedlings at significantly lower costs. There are two separate aspects to seedling quality the genetic constitution and the physical quality of planting stock. The following sections deal almost exclusively with the physical quality of containerized seedlings. Plants with improved survival and growth create better financial and ecological returns, and can generate sustainable enthusiasm and support for institutions to continue or even expand their reforestation programs. In other words, success breeds success, especially with reforestation programs.

This chapter endeavours to draw together the combined experience of nursery managers and specialists worldwide, specifically focusing on the adaptation of currently available root trainer production systems to the unique conditions existing in tropical developing countries.

7.2 NURSERY PRODUCTION SYSTEMS

7.2.1 Nursery production in the tropics: roof for improvement

Tropical and sub-tropical climates are ideal for the establishment and growth of forest tree species. Reforestation with agro forestry program, the decision-makers are faced with a wide array of potential sources of forest tree planting stock for use in their projects, including bare root seedling production, aerial or direct seeding, and containerized nurseries.

In contrast to nursery production in the temperate zone, bare root seedlings are not generally produced in large quantities in the tropics because of the greater heat, moisture, and transpiration stresses.

7.2.2 Raising high quality nursery stock with root trainer systems in the tropics

The level or intensity of management of root trainer nurseries is quite different from that required when using poly-bags. Seed sowing methods and dates, irrigation, fertilization, and other cultural regimes must be changed significantly if quality results are to be obtained. The entire nursery staff will have to be retrained in the more precise and demanding

aspects of root trainer nursery management. Experience shows that it is clearly possible to do so and there are many examples of successful root trainer nursery production in developing countries worldwide.

7.2.3 A. Choosing a root trainer tree seedling production system

Improved root growth and morphology are important goals of any carefully designed root trainer system. Nursery managers and reforestation program directors can feel comfortable that most root trainer systems currently on the market can produce a vigorous seedling with good root growth and orientation, given a good growing medium, proper care and management in the nursery.

In order to choose the proper size root trainer project managers must first determine what size seedling is desired because the size of the root trainer influences the size of the seedlings produced. In general, the bigger the container, the larger the potential size of the seedling, and the longer the time required in the nursery. When deciding on seedling size the degree of competition from weeds and other plants upon out planting, the soil depth and degree of drought-hazard at the planting site, and the particular tree species spatial requirements should be taken into account. For example, Wood (1960) reports that the ideal container size for producing eucalyptus is approximately 90 mm deep, 44 mm wide at the top, with a volume of about 90 cc, and a seedling density of about 420 plants/m^2.

Good weed control on the planting site generally allows for the use of smaller seedlings (and subsequently nursery reduced costs). If the site to be planted has poor weed control, larger seedlings (and thus larger root trainers) are usually required. However, there are occasional exceptions. For instance, relatively small and cheap seedlings produced in root trainers with volumes of approximately 89cc averaged an acceptable 60% survival after one year in farmer-managed agro forestry plantings; even with poor weed control (Whitcomb, 1983). Larger (and more expensive) seedlings may not have fared any better since the majority of the mortality was due to damage from cultivation of immediately adjacent crops by hired labour (Peterson and Smith 1975).

Density of seedlings in the nursery is important. Broadleaf seedlings which are crowded together in root trainers will grow more slowly

become spindly and may suffer from increased disease due to high humidity and poor air circulation (Stoecke ler and Jones, 1957). Stem diameters will be smaller, which may reduce out planting survival and growth (Rao et al, 1990). While Casuarinas and Pine seedlings can be closely spaced with little problems other species, such as coffee, cedar, mahogany and teak, need much wider spacing. Block type root trainer systems only allow changes in spacing when alternate cavities are unfilled; this would be needed to allow seedlings grow larger during the season. Containers with removable cells or tubes, or book type containers permit mid-season corrections in spacing according to the particular cultural requirements of the species being produced.

Lastly, if soils on the planting site are shallow, or if the site experiences occasional drought even during the planting season, then choosing a root trainer with deeper cells can be advantageous. Longer plugs can be planted deeper in the soil to take advantage of soil moisture in lower zones, and thus allow the seedlings to better survive in periods of drought (Peterson and Smith 1975).

Summarizing managers deciding on a root trainer system should focus on issues such as the desired size of the seedling at out planting, flexibility of the system to adapt to different cultural requirements of a number of species, the availability and cost of labor, the ability of the root trainer system to use manual procedures, the short and long-term costs, and the current availability or potential for manufacture within the particular country.

7.3 MOISTURE CONTROL

Control of moisture is critical to proper seedling development, and also influences insect and especially fungal pathogen populations in root trainer nurseries. Root trainer systems that use well-drained and well-aerated potting media often need to be watered more often than poly-bags. But because of the close spacing and small cell volumes, root trainer nurseries use one third to one half the amount of water required in poly-bag nurseries of equivalent production (Perkins, 1973). Over or under watering can be serious problems when nurseries shift from using poly-bags to root trainer systems. Since the small plugs dry out quickly, nursery managers must be trained to check their seedlings twice daily

and to irrigate only when needed, not on a schedule. This helps to avoid over or under-watering. Root trainer systems that can be opened to enable easy inspection of soil moisture are preferred.

While shade cloth-covered shade houses have better air circulation and lower air temperatures than those using plastic films, plastic has been found to be superior for reducing disease incidence, especially when the nursery season coincides with the rainy season [American Association of Nurserymen (AAN), 1977]. Plastic permits the nursery person to completely control the moisture content of media in the root trainers, even during periods of prolonged precipitation, greatly reducing the incidence of soil-borne pathogen attacks. Shade cloth cannot exclude precipitation and forces the manager to heavily rely on fungicides to control soil-borne pathogens. Bamboo and palm leaves are also frequently used for shade in the tropics because they are readily available and cheap but they should be avoided whenever possible, however, as they do not exclude precipitation, and also because they harbor insects and pathogenic organisms.

7.4 CULTURAL APPROACHES

Since root trainer containers are much smaller in volume than poly-bags and intentionally include features designed to maximize growth, it takes a much shorter period of time to produce a seedling, usually only 3-4 months for most species, half the usual length of time. Thus, careful timing of seed sowing is critical if root bound and stunted seedlings are to be avoided.

Seedlings in small containers must be fertilized more frequently than those in larger containers (Whitcomb, 1983). Some root trainer nurseries normally utilize a balanced liquid fertilizer drench of 20-20-20 NPK several times a week for the first 6 weeks or so of the season, followed by a 9-45-15 drench later in the season to encourage root growth and slow height growth (Perkins 1973). Manipulating soluble fertilizer formulations, concentrations, and application frequencies allows the nursery manager to better time the maturation of the seedling with the onset of the rainy season, a distinct advantage. Micronutrient drenches are applied, as needed, usually once every 2 or 3 weeks. Other nurseries mix slow-release fertilizers into their potting media. Nursery manager often

must adopt their fertilization regimes to the pH of the irrigation water, rather than adjusting the water pH, since most nurseries in the tropics lack the equipment and infrastructure necessary to change the irrigation water pH. Specific nutritional requirements for many tropical species have not yet been determined, resulting in over fertilization and excessive height growth in some species and under fertilization and nutrient deficiencies in others.

Proper transplanting of newly germinated seedlings into root trainers is essential if the root training features of the container systems are to be utilized. Poor transplanting (Pricking-out) techniques can result in very serious root deformations causing poor growth and stability upon out planting.

Newly emerging seedlings should be pricked out at the cotyledon stage before the formation of many roots, thus avoiding bent, inverted roots. Personnel transplanting seedlings should be well-trained and closely supervised.

Due to the small size of the containers, root trainer nurseries are somewhat less than other types of nursery production. Indeed, "failure to recognize the fundamental principle that container seedlings require intensive management will inevitably lead to failure and negate the promise of consistent and reliable production of high quality seedlings" (Ossian, 1973). Programs intending to use root trainer systems must have sufficient managerial resources to adequately operate the nurseries. Thorough and comprehensive training of all nursery personnel to assist them in making the transition from cultural approaches used in poly-bag or bare root nurseries to those used in root trainer cultural systems is absolutely essential if consistent, high quality seedling production is to be achieved.

7.5 PACKING, HANDLING & TRANSPORT

Most root trainer nurseries achieve their goal of producing healthy, vigorous seedlings ready for out planting by a predetermined date, usually at the time the rains begin. Yet the nursery's fine work is often squandered because of serious damage inflicted on seedlings when removing from the container packing, transport, and out planting activities. During this final production phase, which ends at the planting site, formally vigorous seedlings are routinely yanked from their containers, crushed, dehydrated,

overheated and suffocated in boxes, and left to suffer in the sun for long periods prior to planting. This abuse inevitably leads to reduced survival and growth and represents large financial losses.

Measures must be taken to protect seedlings on their trip from the nursery to the planting site. Seedlings should be watered thoroughly the night before packing. If seedlings are removed from the root trainers in the nursery, it should be done gently, protecting the plough from root damage and loss of soil. Packing should always be done in the shade to avoid heat and moisture stress. While some programs (e.g. New Zealand Forestry Programme) pack the seedlings in alternating layers in a cardboard box lined with a sheet of plastic, other programs utilize wooden boxes or plastic bags. This approach can result in loss of soil from the root plug from abrasion and vibration during transport, poor aeration, and overheating of the seedlings. Seedlings shipped in this manner must be planted immediately upon arriving at the planting site, regardless of the weather conditions. A method developed in Haiti is to pack the root trainer grown root plugs in a plastic bag (25 seedlings or so to a bag, with the leaves emerging from the bag), and then put the bags in a box (Patterson, 1975). Using this system, soil adheres better to the root plug and crushing and abrasion damage is minimized. A similar system is used in the FINNIDA project in South Kalimantan with Enso pots. Once arrived at the planting site, the plastic bags containing the seedlings can be removed from the box, stood upright, and watered as needed until planting conditions are optimum.

When using containers with portable cells, such as the Ray Leach Single Cell System, Hawaii Dibbling Tubes, etc., the seedlings can be transported to the field protected within their containers, a major advantage since physiological deterioration of the seedling is avoided (Davis and Whitcomb 1977). They will require more transport space however, and it may be difficult to collect the containers after out planting is completed, especially in agro forestry programs working with small farmers.

Finally, the very best seedlings can be rendered useless by poor planting methods, poor site preparation and weeding, and poor post-planting care and protection. Any nursery program must be part of a

larger program emphasizing proper implementation of these basic reforestation techniques.

Nurseries in tropical developing countries are currently producing hundreds of millions of trees every year, mostly using antiquated methodologies and techniques. Seedling production in polybags is labor and space intensive and produces seedlings that are large, heavy and difficult to transport. They frequently have severely deformed root systems which will take time to function properly, which may compromise growth in later years, significantly reducing the production capacity and potential environment on economic impacts of any reforestation or agro forestry program.

It is obvious, project and nursery managers wishing to improve the cost effectiveness, efficiency, and productivity of their seedling production operations should seriously consider switching to root trainer tree production systems. Better root growth, form, and vigor avoidance of spiral roots (with its long term investments implications) simplification of insects and disease management, lower labor costs, smaller quantities of potting media, reduced cultural, handling and transport carts, and better initial survival and subsequent growth of out planted seedlings, are persuasive arguments for change. Clearly, the modest initial investment required to change to root trainers can result in large gains in seedling quality, productivity, and cost effectiveness (World Bank, 1993).

7.6 LOW-TECHNOLOGY TECHNIQUES FOR THE VEGETATIVE PROPAGATION OF TROPICAL TREES

Stem cuttings of five tree species from dry and semi-arid woodlands (*Acacia tortillas*, *Prosopis juliflora*, *Terminalia spinosa*, *Termininalia browni* and *Albizia guachapele*) and seven species from moist tropical forests (*Cordia alliodora*, *Vochysia hondurensis*, *Nauclea diderrichii*, *Ricinodendron heudelotii*, *Lovoa trichiliodes*, *Gmelina arborea*, *Eucalyptus deglupta*) have been easily rooted in improved low technology, high humidity polythene propagators. These propagators, which are cheap to construct, are very effective and have no essential requirements for either piped water or an electricity supply. Experiments have tested different rooting media, auxin applications and compared mist versus non-mist propagation.

Assessments of the physical and gaseous environment of the propagators has indicated ways of improving the rooting environment through and understanding of the sensitivity of the relative humidity to radiant energy and to opening the propagator for short periods (e.g. 2-3 minutes).

It is now widely realized that vegetative propagation and clonal selection offer a means to greatly enhance the yield and quality of forest products from commercial plantings in the tropics (Williamson, 1983). However, there is a need to simplify the technology so that vegetative propagation can be achieved in the absence of electricity and a piped water supply. In addition, in many tropical countries, the high capital & running costs of currently available propagation systems make them inappropriate except for research or large-scale commercial projects.

The environmental requirements for root initiation in leafy stem cuttings are those that minimize physiological stress in the cutting. In general terms this means using shade to lower the air temperature and, by providing a high humidity, to reduce transpiration losses. By the latter, the vapour pressure of the atmosphere surrounding the cutting is maintained close to that in the intercellular spaces of its leaf.

There are numerous propagation systems used in commercial horticulture. These are usually based either on spraying mist, fogging or enclosing in polythene. The advantages of polythene systems have been known for many years (Wood, 1960) and they have been used to propagate tropical hardwoods with good success.

Recent work by the Institute of Terrestrial Ecology (ITE) and its overseas collaborators has applied and improved the design of non-mist propagators for use with a wide range of timber and multi-purposes tree species from both tropical moist forests and semi-arid areas (Whitcomb, 1983). Recent studies with *Triplochiton scleroxylon* cuttings under intermittent mist have indicated that rooting ability is related to the production of reflux - soluble carbohydrates, apparently derived from current photosynthesis while the cuttings are in the propagation unit. Furthermore, it seems that the ability to produce these carbohydrates is related to the pre-severance light environment and nutrient status of the cuttings while on the stock plants. Both the total irradiance and the light

quality (red: far-red ratio) are important components of the pre-severance light environment and these factors interact with nutrient availability to influence the rates of net photosynthesis and rooting. These variables to a large extent account for the variation in the rooting ability of cuttings of *T. scleroxylon* taken from different shoots of variously-treated stock planes (Morey et al. 1985).

Juvenile shoots of twelve tree species (Table 7.1) have been used as leafy stem cuttings. The studies presented here were done in either glasshouses in the UK or under nursery conditions in Costa Rica, Kenya and Cameroon (Leaky et al, 1991). In all instances however. 22-27 °C the cuttings were prepared as described below and set in randomized block. The numbers of replicate cuttings per treatment were between 24 and 117. Standard errors for percentage rooting were calculated using the procedures of Barber (1984) for data with binomial distributions.

Table 7.1. Tropical tree species vegetatively propagated using simple, low-tech propagators in Costa Rica, Cameroon, Kenya and Great Britain. (Leakey et.al. 1991)

Species	Family	Range	Uses
Gmelina arborea Roxb.	Verbenaceae	Indo-Burma region, And S.E. Asia, a Pan tropical exotic	Timber
Eucalyptus deglupta BL.	Myrtaceae	Tropical Australasia, a Pan-tropical exotic	Timber
Nacuclea diderichii (DcWild & Th Dur.) Mcrr.	Rubiaceae	W. and C. Africa	Timber
Lovoa trichilliodies Harms Ricinodendron-heudelotii (Baill)	Meliaceae	W. and C. Africa	Timber
Pierre ex Pax	Euphorbiaceae	W. and C. Africa	Fruit
Cordia alliodora (Ruiz&Pav.) Oken	Ehretiaceae	America	Timber
Vochyasia hondurensis Sprague	Vochysiaceae	C. America	Timber
Albizia guachapele (Kunth) Dug	Mimosaceae	C. America	Timber
Prospois juliflora (Swartz)D.C	Mimosaceae	C. America	Multipurpose

Contd....

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Species	Family	Range	Uses
Acacia tortilis (Forsk.) Hayne	Mimosaceae	W. and E. Africa	Multipurpose
Terminalia spinosa Engl.	Combretaceae	E. Africa	Multipurpose
Terminalia brownii Fresen	Combretaceae	E. Africa	Multipurpose

7.6.1 Preparation of cuttings

Cuttings were harvested from seedlings, managed juvenile stock plants or coppice shoots. Depending on the species, 1-to 4-node cuttings were used. These were usually about 50-60 mm long and with a leaf area of about 50 cm^2 (Whitcomb, 1983). In large leaved species, leaf areas were reduced by trimming prior to severance. The basal end of cuttings were dipped briefly in indole-3yl-butyric acid solutions (0.2-0.4% IBA in industrial methylated spirit) to a depth of about 2-5mm, and the alcohol then rapidly evaporated off in stream of cold air from a fan (American Association of Nurserymen, 1977). To minimize stress, the cuttings were inserted in the propagator as soon as they were dry. Alternatively, commercial auxin-based rooting powders "Strike" and "Seradix 2" (May & Baker Ltd) were used (American Association of Nurserymen, 1977).

7.6.2 The non-mist propagator

The propagator design currently in use is based on the American Association of Nurserymen, 1977 modified by Morey et al., (1985) and now further modified so that it does not require daily watering. Basically, a wooden or metal frame is enclosed in clear polythene so that the base is water-tight. The frame also provides support for the enclosed volume of water. The polythene base of the propagator is covered in a thin layer of sand to prevent the polythene from being punctured by the large stones (6-10 cm), which are placed on it to a depth of 10-15 cm. These stones are then covered by successive layers of small stones (3-6cm) and gravel (0.5-1.0 cm) to a total depth of 20 cm. The gravel provides support for the rooting media, which is the uppermost layer, while the space between the stones, are filled with water. A length of hollow bamboo provides an open cylinder inserted into the medium and stones which is used both to observe the water level and to add water if necessary. The rest of the

frame is covered tightly with a single piece of clear polythene, and a closely fitting lid is attached. Internal supports to the frame at the level of rooting medium also provide subdivisions allowing the independent use of different rooting media. A similar frame to that of the non-mist propagator, with roll up polythene sides, can be used as in Costa Rica, as a weaning area (American Association of Nurserymen, 1986).

7.6.3 The propagator environment

In tests run in ITE glasshouse, in which air temperatures were maintained at about 20°C temperatures in non-mist propagators rose to a mid-day peak of about 34°C during bright, sunny, mid-summer weather. This rise in temperature was associated with a decrease in relative humidity from about 95% to about 75% .

This represents a substantial increase in the saturation vapour pressure deficit (SVPD) of the air from 0.02 kPa to 1.37 kPa. An important decrease in relative humidity also occurred when the propagator was opened for five minutes at midday. In this instance relative humidity decreased by about 40-50% to glasshouse ambient within two minutes, representing an increase in evaporation rate of approximately x 4.5 (SVPD = 0.45 kPa to 2.08 kPa). Relative humidity increased rapidly again following closure of the lid. Decreases in air temperature to ambient were also associated with this period of opening. Subsequent gain in the temperature resulted from closing the propagator, but the response time for temperature was considerably slower than for relative humidity.

When the easy-to-root species *Nauclea diderrichii* was used for physiological studies in a non-mist propagator in Edinburgh University, it was found that cuttings had maximum rates of photosynthesis that were typical of intact plants, up to 6μ mol CO_2 m^2s^1 at an irradiance of 1000μ mol m^2s^1. However, the photosynthetic capacity of these cuttings was influenced by changes in the CO_2 concentration inside the propagator. In the middle of the day, the CO_2 concentration fell to 150 μ *mol mol*^{1} while by midnight it rose to 550 μ *mol mol*^{1} reflecting daytime assimilation and night time respiration, respectively.

With regards to rooting media, the water-holding capacity of a fine-gravel (2-3mm diameter) medium was considerably increased, at the expense of the volume of the air spaces by the addition of rotted sawdust (50% by volume).

7.6.4 Rooting tests

In Costa Rica, studies using five tree species investigated the effects of four different rooting media (i) gravel, (ii) 50:50 gravel with saw dust, (iii) fine sand, and (iv) 50:50 fine sand and sawdust. Each medium was tested with cuttings dipped in a range of IBA concentrations (0, 0.05, 0.1, 0.2, 0.4 and 0.8%). There were, however, substantial differences between species with regard to rooting success on the different media. Single-node juvenile cuttings of all five species rooted well (70-95%) on their best medium. *Cordial alliodora* rooted best in fine sand, with or without sawdust,

The rooting of *Vochysia hondurensis* cuttings was detrimentally affected by the incorporation of sawdust into both gravel and fine sand. On the other hand, sawdust enhanced the rooting of *Eucalyptus degulpta* cuttings in both gravel and sand, while *Gmelina arborea* and *Albizia guachapele* rooted well in all media. Unlike these juvenile cuttings, mature cuttings from vigorous shoots in a heavily pruned crown of *G. arboreal* rooted much less well especially in pure gravel. In juvenile *G. arborea,* a comparison between cuttings set in fine sand under an intermittent mist propagator and the non-mist propagator showed better rooting in the non-mist propagator (American Association of Nurserymen, 1986).

C. alliodora, A. guachapele and *V. hondurensis* differed in their responses to the range of IBA concentrations (0 to 0.8%). Optimal concentrations would appear to be 0.4, 0.1 and 0.2% IBA respectively for the tree species. In addition *C. alliodora* did not root at all without applied auxins, while rooting in untreated *V. houdurensis* cuttings exceed 40%. Cutting of *A. grachapele* were very responsive to all auxin treatments.

Studies using non-mist propagators in Edinburg and in Kenya, with tree species from semi-arid areas, investigated the relative merits of two commercially available, rooting powders (i) "Strike" = 0.25% NAA, and (ii) "Seradix 2" = 0.8% IBA. Seradix-treated cutting of *Acacia tortillas, Terminalia spinosa* and *Terminalia brownii,* rooted better than those treated with Strike, while for *Prosopis juliflora,* rooting percentages were above 90% with both treatments.

Two-node cutting of *P. Juliflora* also rooted relatively easily without applied auxins, although IBA solutions (0.4-0.8 %) did hasten rooting and increased the numbers of roots formed. Long cuttings tended

to root better than short ones, although there was no relationship between cutting length and its position of origin on the stock plant. Cuttings from lower on a stem generally rooted better than apical ones. An experiment comparing rooting under mist, with rooting in a non-mist propagator, clearly demonstrated the advantages of conditions without mist. A third treatment, in which a mist propagator was enclosed in polythene, resulted in even less rooting and higher mortalities due to rooting. When non-mist propagators have been used in Kenya to produce clonal material of *P. juliflora* for field experiments, the success rate was greater than 75%.

Like those of *P. Juliflora*, cuttings of *A. tortilis* and *T. spinosa* are also much more easily rooted in the high humidity conditions of non-mist propagator. There is, however, very considerable clonal variation in rooting ability in these species, and cuttings of *T. brownii* have so far only been rooted with a low rate of success.

In Cameroon, the percentage rooting of cuttings of *Lovoa trichiloides* was relatively poor (c.40-50%), and, in addition, the results were frequentiy unexpected. For example, no beneficial effects on rooting were found following the application of NAA or a range of IBA concentrations (0-200 mg/cutting), either in terms of the percentage of cuttings rooted or the roots per cutting. Furthermore, the optimum leaf area seemed to be very high at about 200 cm^2 per cutting.

When the rooting of cutting of *Ricinodendron hudelotii* was tested both under mist and non-mist propagators with 'Seradix2', rooting by day 21 was best without mist (75% v 50% under mist).

The 'low-tech', non-mist propagators described here therefore seem to provide a very practical solution to the problem of how a wide range of tropical tree species can be propagated vegetatively. The advantage of these propagators seems to be particularly great for the dry-zone species, which can be very susceptible to rotting under mist.

While it is clear that the environment within the non-mist propagator fluctuates considerably over the day in response to variations in ambient temperature and incident radiation, it is also clear that by being enclosed and continuously moist, the cuttings are not subjected to the extremes of saturation and water stress that can occur when misting frequency is poorly matched to changes in the weather.

An improvement, which might further stabilize relative humidity in the non-mist propagator, would be to construct the lid in several

sections. Then the whole propagator would have to be opened to access the cuttings. Ideally, the propagators are opened as little as possible and especially not during the heat of the day. When propagators are opened the cuttings should be sprayed frequently with a fine spray of water from a hand-held or knapsack sprayer. During bright sunny weather, shading is essential and spraying is highly desirable to prevent low relative humidity developing at mid-day. Attention to these points of detail is likely to be particularly important when propagators are used in hot, sunny and dry areas.

The reason why the rooting of cuttings of different species has slightly different requirements with respect to propagation media, and auxin concentration, is unknown. Studies are in progress at the Institute of Terrestrial Ecology (Leaky et al, 1991) and are aimed at the identification of fundamental principles determining rooting ability in a range of tropical tree species. In this regard it appears that stock plant light/nutrient interactions prior to severance are important affecting the subsequent capacity of uprooted cuttings to photosynthesis. This photosynthesis could also be limited to low daytime CO_2, concentrations in the propagator. Thus it may be necessary in future to enhance CO_2 diffusion into the propagators (American Association of Nurserymen, 1986).

7.7 BIOFERTILIZER APPLICATION TO FOREST NURSERIES

The continuous use of chemical fertilizers, indiscriminate use of pesticides, poor crop, soil and water management, have not only decreased the productivity of soil, but also increasingly polluted the environment, causing serious health hazards to the entire biosphere. Also, in the light of recent global fertilizer shortage (both organic and inorganic) an intensive search for potential sources to supplement and/or substitute fertilizers through cheaper biological means has become imperative (Kumaravelu, 1993).

At this juncture, keeping all these in mind, use of bio-fertilizers throughout the world is becoming popular. 'Biofertilizer' literally means 'Life-fertilizer'. Biofertilizers are one among the numerous microorganisms, which live in soil (or) inside the roots of plants, and are beneficial to the plant as well as to the environment. Bio-fertilizers, which are widely used, are *Azospirillium, Phosphobacteria, Rhizobium* and *Azotobactor* (Jayabalan, 1993).

Azospirillum, Rhizobium and *Azotobactor* are free living Nitrogen fixing bacteria and their population in untreated soil is usually very low; 102 to 104 in 0" to 6" depth of soil. When we apply these biofertilizers either directly to the soil or through seed coating, these multiply in enormous numbers and they absorb pure nitrogen from atmosphere and release required nitrogen in a sustained manner, so much so, it prevents the plants from nitrogen starvation. Among these three, *Rhizobium* is applied only to the leguminous plants, which forms root nodules. Thus all these biofertilizers improve the rate of seed germination, help in root proliferation, accelerate plant growth, and initiate early flowering and maturation. Phosphobacteria help in the mineralization of Tri-calcium-phosphophate and other nutrient complexes and thus increase the uptake by the plants. Out soils are naturally phosphorous deficient and by applying these micro-organisms, we can increase the uptake of phosphorous, which is essential in the development of root system.

For the first time in our country, 17 Lakhs forest tree seedlings have been inoculated with bio-fertilizers like Azospirillum, Phosphobacteria and Rhizobium at the rate of 1 gram per seedling by the Research wing of the Tamil Nadu Forest Department in their nurseries raised for supply of seedlings to catchment area planting under World Bank supported Tamil Nadu Agriculture Development project.

It is of interest to note that at Mukkombu Nursery, the average survival percentage of all the 10 species planted in the different treatments, when compared to the control, is more.

Results obtained at Mukkombu, Tamil Nadu, India.

Height increase over control in percentage:

Azospirillum	-	80.67%
Phosphobacteria	-	41.01%
Rhizobium	-	60.67%
Azos + Phos + Rhizo	-	55.25%

Biomass percentage increase over control:

Azospirillum	-	25.6%
Phosphobacteria	-	37.2%
Rhizobium	-	28.3%
Azos + Phos + Rhizo	-	32.4%

Thus, by applying these bio-fertilizers, we can overcome seedling mortality during the early years following planting.

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8

SEED TECHNOLOGY

8.1 INTRODUCTION

In agriculture, collecting seed from superior parent stock has been practiced for thousands of years. This technique results in higher yield and environmentally durable plant. This concept, however, has to gain widespread acceptance in forestry practice. To maximize yields and quality of trees for plantations, agro forestry, and other uses the following principles for collecting seed should be observed (Hibbered, 1991).

8.2 SEED COLLECTION

In forestry, as in agriculture, the quality of offspring plants will be better if the seed used to produce them was collected from superior individuals, stands or orchards. Seed quality is measured in two ways. One, by the physical quality of the seed and secondly, by the desired physical traits of the resultant mature tree. The benefits of using better quality seeds, chosen from selected parent trees, are twofold: improved survival and greater economic returns.

8.2.1 Improved survival

Seeds from healthy, well formed trees provide greater assurance that resulting stock will have good form, survive and better resist stressed conditions due to marginal sites, frequent cutting, or harsh climates.

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These adverse conditions typically weaken all but the strongest trees, making them vulnerable to insects, fungi, parasitic plants, and disease.

More important because of the long-term resource investment and land and labour commitment in forestry, high survival rate of trees is important.

In agriculture farmers can recoup their losses after a poor season or even two. Trees, however, occupy a site for years. Therefore, any reduction in growth or quality from planting inferior stock represents a lost opportunity, which can be measured in time and capital, for as long as a tree occupies a particular site.

8.2.2 Higher product yield

For the second benefit, economic return, the investment in seed selection will be more than compensated for by higher product yields over shorter rotations. Better yield result in more building materials, higher fruit production and quality, faster fuel wood growth and quicker and more prolific regrowth after lopping.

8.2.3 Simple measures are most effective

Effective seed selection can create success, even though sophisticated techniques may not be used. Any attention given to seed source will be a measurable improvement over current practices.

In addition, careful seed handling practices must be included as part of the seed collection process. Such practices include transport, seed preparation, handling, cleaning, grading and seed testing.

Disregarding these practices will result in damaged or poorly developed seeds and allow the inclusion of unwanted or excessive amounts of foreign materials, which hinder germination and plant production.

The following sections in this chapter describe how to develop a system of proper seed collection and handling practices.

8.3 PLANNING THE SEED COLLECTION STRATEGY

Too often in large planting programs the task of seed collection is an afterthought, typically left until the last minute and done hurriedly by unskilled or untrained labor while final nursery preparations are being made. Small-scale planters usually have access to leftover seeds from

large programs. In either case, little consideration is given to seed quality, form or location of the parent stock.

Sometimes, to satisfy the required seed volume, nursery managers purchase bulked seed from villagers. However, villages tend to collect from the nearest trees or stands, which generally include immature, diseased, distressed and otherwise inferior seed.

And if seed needs to be collected from the crown, villagers will choose the easy-to-climb trees, which are typically small. Such trees would not normally be chosen as prime seed source candidates (Singh and Veerendra Singh 1982).

Also, in some species a single tree will produce a large amount of seed in some years. Such a harvest may satisfy the bulk requirement, but would be genetically dangerous because only one phenotype is represented. This technique causes problems for both large and small scale planters.

8.4 CAREFUL PLANNING AVOIDS WASTE TIME, EFFORT

Approach, using untrained labor or collecting seed from a single tree, can be a critical mistake. Such practices often result in low survival, substandard trees, and a poor economic return for the time and work invested, for example nursery and site preparation costs.

Instead of an impromptu search or purchase from unknown sources, any seed collection, both small scale and large scale, should be a developed program of scheduled activities overseen by knowledgeable individuals. This is especially true for those involved in large scale planting programs; those involved in small-scale planting can often request advice from nearby large-scale planters.

The essential activities include selection of preferable parent trees; preparation of equipment including provisions for handling, transport, extraction, testing, grading and storage; recruitment and training of workers and seed sampling and quality monitoring. A timeline and work plan for the collection itself should be developed in conjunction with overall nursery operations. Most important of these is the selection of preferable parent stock. An able person who can distinguish between desired and inferior seed sources can accomplish this. This person, in turn, can supervise field seed collection during harvest.

Incorporating many of these activities often requires the level of funding available to large-scale operations. Never the less, even the small-scale planter should apply the principles as best possible whenever collecting seed (Hibbered, 1991).

8.5 GENETICS PROVIDES THE BASIS FOR SEED SELECTION

Why is it necessary to collect only from certain preferable trees? Tree improvement programs worldwide have shown that seed collected from trees with particular traits tends to produce trees with similar traits. One can correctly assume that if good parent trees are selected, then most of the resultant offspring will be of desirable quality. Yet despite this concept's proven value and wide understanding, it is seldom applied in the field. To correct this shortcoming, simple parent tree selection guidelines should be developed. These would identify the desired traits and specify the parent trees that reflect those traits. Such traits might include straight trunks, fast growth, and better form.

These guidelines are normally met in national or company research programs, but following them will benefit all planters who are careful about the source of their seeds.

The traits in turn are chosen to reflect the ultimate desired use of the tree, including building materials, windbreaks, shade, fuel wood, food, fodder, or erosion control.

At the same time, these guidelines should not be made cumbersome. For the benefit of those individuals collecting seeds the guidelines could be a condensed set of simple criteria.

Indeed, immediate benefit can be derived from using even the most basic concepts such as selecting trees of good form and vigor and avoiding trees that are poorly developed, diseased, dying, or are insolated from others of the same species. These simple methods should be applied to large and small programs.

8.6 COLLECTION STRATEGY INCLUDES AREA, NUMBER AND SPACING

While it is important to collect seed from the best parent trees it is also important to gather seed from several parent trees. Collecting seed from several parent trees assures diversity among seedlings being planted.

Whether the program is large or small, maintaining diversity is important and will help guard against pest epidemics.

To obtain adequate diversity, seed lots should be collected from a number of trees. In plantations and along roads more emphasis should be placed on collecting from the best trees. In all cases care should be taken to collect seed from several tree representatives of the best parent stock. Researchers have yet to determine an ideal number of trees per seed lot, i.e. those seeds that will be used in one planting. However, most agree that collection should not rely on only one or two individual trees. According to some sources, minimum of 15 to 25 parent trees per bulked seed source is preferred.

Furthermore, collection should cover a broad geography, including the environmental extremes at the edge of the range. Seeds selected from a narrow sampling of trees should be avoided as this will limit genetic diversity. Keeping a proper distance between selected parent trees in natural stands is also vital. During natural regeneration of some species seeds fall near the parent. At times inbreeding may occur, which will result in lower quality individuals. To reduce the chance of collecting a seed lot predominated by such trees a 100-meter distance between collection trees of the same species is recommended. This practice is especially critical to species that are looped or coppiced as a method of harvest and regeneration.

The temptation to forego a minimum number and spacing strategy is perhaps greatest during years of abundant seed production. Here large seed quantities are available from relatively few trees. At such times, an even greater effort should be made to ensure genetic variety.

Even better, abundant seed years can be opportune. When properly cleaned and prepared, seeds of some species can be stored for several years. Stored volumes of good seed will help ensure supplies during production cycles. Where possible, all large-scale planting programs should have at least two years of seed supply in storage.

Conversely, leaner seed years present other challenges. During such years shortfalls will occur and the urge will be to collect for quantity without regard to quality. If at all possible, seed collection during lean production years should be minimized (Anon, 1991).

8.7 PROPER SCHEDULING IS VITAL TO QUALITY

Aside from generic and site qualities, other considerations must be factored into the collection strategy.

For instance, only mature seed from ripened fruits should be gathered. Harvest schedules must account for the different times at which fruits from various species ripen. Depending on species and even different trees, seeds can be mature for a period of two to six months. To help determine when seeds are ready for collection periodic surveys of the selected stands is recommended. Survey should begin after flowering, as is the practice with cocoa. To prevent any false readings, specific sample trees should be marked and used throughout the process.

The surveys will also serve as an early indication of the season's expected seed volume and quality. In addition, field surveyors should look for early infestations of insects, disease or other seed predators.

With such information, the harvesting strategy and schedules can be adjusted to accommodate any foreseen hindrances.

8.8 WHY COLLECT SEED FROM SEVERAL PROVENANCES ?

Differences in how trees adapt to environment is often more important within a species than among species. There can be important differences in growth between seed sources from different geographical areas and environments. The areas and environments in which stands have developed through natural selection are called provenances. The growth, measured in height, in tropical hardwoods of the most vigorous provenances can be 30 to 50 percent greater than the growth in the least vigorous provenances (see figure 8.1). Unfortunately, there are very few tree species that have been adequately explored in their center of origin and studied in provenance and progeny tests on multiple sites, leaving much uncertainty about provenance which is intended to represent an entire species. Perhaps the most striking example of this comes from the use of *Acacia mangium* in Sabah, Malaysia where ultimately thousands of hectares were planted from seed collected from one tree. As a result, growth rates of the third generation were one-half those of the first generation (Technical Bulletin, World Bank, 1992).

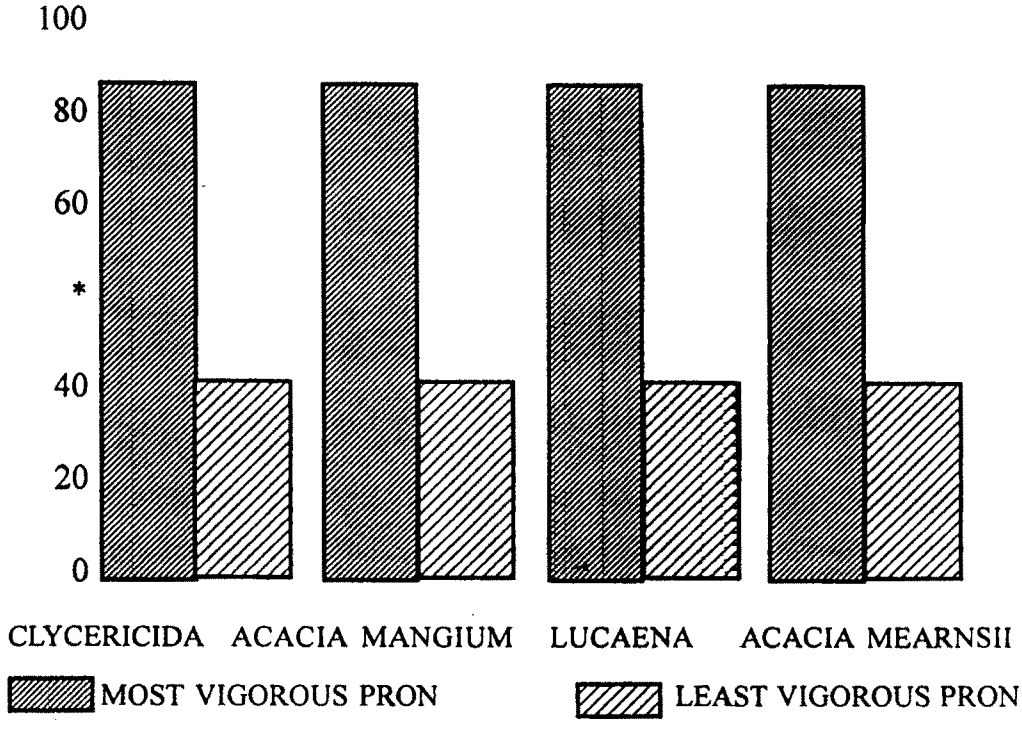


Figure 8.1 Tree growths can be improved 30 to 50 percent using seeds from the most vigorous provenance.

8.9 A FIELD STRATEGY

8.9.1 How to select good trees

Parent tree selection in the fields is best done as a planned team effort coordinated by a trained person.

This selection of preferred trees serves to eliminate errors that would otherwise be produced by last minute collection efforts. In addition, a planned, timely program allow for the full use of available people and resources.

Development of the collection strategy includes a series of routine screenings of potential parent stock. The series is broken into three progressive phases.

Phase one is done well before the onset of flowering. Give simple guidelines for site selection and appearance, general laborers search for appropriate stands. Locations of such are recorded, along with general descriptive information.

Phase two involves technical staff. Here, the identified stands are reviewed for their potential as a seed source. The review includes analysis of the site makeup including soils and topography; species composition, volume and spacing, and age, size and health of the trees.

Initial selections are made as to potential parent stock. These trees are marked for further study in phase three.

In phase three, trained professionals examine the marked trees for a final selection. The trees are analyzed for their physical characteristics, including their form, branching, growth rate, dominance, crown cover, health, and any clues as to their seed productive capabilities.

Before the final candidates are chosen, additional criteria are again considered. This includes the previously mentioned spacing preference of at least 100 meters between individuals of the same species. And, preference will be given to those trees located in the stand's perimeter.

Finally, selected trees are marked and their location recorded. Monitoring will increase as flowering begins and continue through the seed harvest period. Monitoring includes volume and quality of the seed as it matures in addition to any indications of infestations including insects and disease (Tewari, 1991).

8.9.2 Seed handling and preparation

Seeds are rarely taken directly from the collection site for immediate planting in the nursery.

Instead, they must first undergo preparation that will ensure proper germination and help eliminate bad or damaged seed. Preparation includes all activities from collection to sowing, such as transport, sorting, extracting, cleaning, grading and testing.

In addition, seed harvesting and sowing periods are often months apart, which requires adequate storage containers. The containers must protect the seed stock from the weather and intrusive pests such as animals, insects or molds.

In some instances, proper temperature control may also be required, especially if seed is to be kept over a number of years.

8.9.3 Handling in the field

Once the fruits are picked or collected, they must be transported

directly for seed processing. Any time lag in the field can cause dehydration or predation by various seed pests. The seeds must also be well protected from the weather to prevent excessive contact with moisture, which may prompt early germination.

In addition, because of the variation in harvested fruits, handling techniques must be flexible. Those in charge of seed storage must have adequate knowledge as to each species requirements and limitations during transport. For example, while the hard coated seeds of most leguminous species travel well, other seeds are more fragile and require greater handling care.

The nursery manager must have facilities readied for seed preparation at the time of collection.

8.9.4 Proper conditioning limits of seed degradation

Such facilities should be located at the nursery site, thus eliminating the need for further transport before sowing.

Seed extraction should occur as the fruits arrive from the field. Again, any lag between collection and preparation will cause the seed to degrade or spoil.

Depending on species equipment for both dry and moist extraction may be needed. Dry extraction requires appropriate sorting and drying areas, tumblers, and screens for sieving moist extraction calls for removing the fleshy outer coating of the seed, or the fruit, followed by drying and cleaning of any remaining foreign materials.

In either case, all foreign materials must be removed as these can result in poor germination or hamper storage ability.

Also the rate of drying and moisture content must be carefully monitored during the drying process. Seeds dried too quickly may become damaged.

While small-scale planters may not have access to sophisticated equipment for drying and cleaning seeds, they should aim to remove as much foreign material as possible.

After extraction, the pure seed is then graded. Grading helps ensure a more homogenous seed set, which in turn will produce more uniform growth in the nursery.

Grading is done either by seed size, weight, or a combination of both. Actual seed size within the same species will vary due to a number of factors. The goal is to eliminate undersized, immature, or deformed seed. This usually can be done by hand if great quantities are not required. However, graders must be provided samples of the desired well-graded product to use as a guide (Anon, 1991).

In addition to grading, seeds are tested for germination rates, and are examined for phytosanitary concerns and species purity.

Using these factors, the forester must develop criteria for consistent seed certification. No matter how carefully done, collection efforts in the field will be nullified if inconsistent methods of grading and testing are used from one seed lot to the next.

8.9.5 Proper storage is essential

If the prepared seed is not used within a reasonable period of time, adequate storage must be provided.

As noted, most leguminous seeds store well in normal conditions provided they are properly cleaned, dried, and protected. Such prepared intact seed can be handled and stored without fear of damage.

However, if storage is required for several years, special facilities, such as cold storage may be needed for some species.

On the other hand if germination begins, different measures must be taken. Here the seed ceases dormancy and begins to use stored nutrients for survival. At this point, its shelf-life is drastically reduced.

8.9.6 Take note of growing sites

Aside from desired end-use traits, the tree must adapt to its growing site. In particular, it must withstand periodic harsh conditions, such as drought, and be able to grow in poor soils.

Physical traits of parent trees alone may yield few clues as to site adaptability. Here, environmental distinctions may help.

The collection staff should note even the slightest variation through out a species; range, topography soils, microclimate, associated vegetation, and man-caused factors such as animal grazing may all influence how a species conforms to its surroundings.

In overall location, a species typically grows best in middle of its range and fares less well at the edges.

However, seed lots should reflect all site variations, thus assuring that no one habitat is relied on too heavily.

But some cautions are needed when sampling for habitat, when associated plants are used as site indicator species, one must distinguish between natural conditions and manmade alterations. For example, continual grazing can heavily degrade a site, even to the point where it changes the vegetative makeup (Technical Bulletin, World Bank, 1991).

In addition, extreme dry or wet areas should be excluded if not within the normal bounds of a species' requirements.

During collection of particular stands, efforts should concentrate on trees that comprise the stand's perimeter. These individuals produce better quality seed.

Aside from natural areas, manmade stands should be reviewed carefully before selection as a seed source. For example, early reforestation efforts may have given little thought to seed collection, thus producing inferior parent trees to those found in natural stands. Or, the species planted on the site may not be well suited for the area. Whenever possible, historical data or records should be referred to for such stands.

8.9.7 A short list of collection tactics

- Collect seed lots 15 to 25 individuals that are spaced at least 100 meters distance from any other collection tree of the same species.
- Choose trees in vigorous health and avoid any that are diseased, suppressed, deformed, environmentally stressed, or in otherwise poor health.
- Collect from trees well formed and either dominant or co-dominant in the canopy.
- Avoid trees that are isolated from others of the same species.
- Harvest only mature seed from ripened fruits.
- To ensure genetic variation, collect fruits equally from all parts of the crown-top, sides, and bottom-as these parts may have been pollinated at varying times from different sources.
- Collect throughout a species normal habitat, noting variation in site.
- Man-made stands, including live fencing plantations, or windbreaks, should be carefully reviewed as to their establishment before being selected as a seed source.

8.10 SEEDLING QUALITY

8.10.1 Quality versus quantity

A nursery manager's most important goal is to produce quality trees. Quality is more important than quantity. It is a common mistake in nurseries to concentrate on the total number of trees produced and neglect their physical and genetic quality. It is better to produce a few good trees, than many poor ones. Improving plant quality may mean that the farmer plants fewer trees, but the growth and survival of these trees will be superior.

Good plant quality is the basis for tree planting success. It is not worth a forester's effort to transport plants to the field, prepare an area, plant and maintain trees unless they are of good quality. A poor quality tree will always be one even if planted on a well-prepared, good site. In the field, each poor quality tree wastes space and resources leading to low site productivity. High quality trees have a higher survival rate and faster growth in the field than poor quality trees. Fast growth allows a tree to out compete with weeds and reduce the initial labor costs of establishment. Fast growth also enables a farmer to harvest wood or tree products, sooner, increasing the return on the farmer's investment. We are producing trees for people's livelihood; they depend on having high quality tree (Kumaravel, 1993).

Seedling quality has two main aspects. The first is the genetic quality or the sources of the seed; the second component of seedling quality is its physical condition when it leaves the nursery. Improving genetic quality of seedling requires a long-term strategy of seed selection, while improving the physical quality can be accomplished in just one or two seasons.

8.10.2 Seed source quality

Farmers select only the best animals for breeding; animals that are small and sickly do not produce good offspring. Similarly, farmers use only the superior crops that have high yields and are resistant to disease for the next year's seed. These same principles should apply to trees. The characteristics of the parent trees can greatly influence the characteristics of the seedling. The seed can determine whether the tree will grow well or poorly. Studies from around the world have shown

that good seed improves survival, timber and fruit quality, and shortened rotation or harvest times,. Because trees take longer to mature than crops or animals, thus making tree planting a long-term investment of labor and land, it is even more important to select only high quality seed (Wightman, 1999).

The desired characteristics of the parent trees will vary depending on whether the trees are for wood, fodder, fruit, or medicine. A good nursery practice is to consult farmers as well as forestry technicians when selecting the seed sources. Farmers often know additional traits, which make their trees more valuable. It may be difficult to find some of the trees with the best traits because these are often the first to be cut down. Conserving some of the best trees within the community will ensure future supply of seed.

Some desirable parent tree characteristics are:

- Healthy trees with a large, well developed crown
- For timber trees, a long, straight trunk with few branches
- Wood quality, such as high density, or straightness of the grain
- For fodder trees, palatability and digestibility of foliage (leaves that animals like to eat and are easily converted into energy)
- For fruit trees, low branching may be desired for easier fruit harvest
- Fruit quality, such as sweetness or ability to be transported with minimum damage
- Fast growth rate
- Low susceptibility to (or ability to quickly recover from) disease or insect attack.

A Good nursery practice is to select the parent trees well in advance, and plan a way to ensure sufficient seed is collected. Permanently marking the trees as seed sources may help ensure that they will not be cut down. Only mature seed from ripened fruit should be harvested. A Good nursery practice for each species of tree is to collect seed from at least 30 parent trees that are at least 100 meters apart. If you buy the seed, find out how many trees were used. Using a large number of seed sources increases the gene pool or genetic diversity of the seedling. Genes are the codes of information from the parent trees that determine how the progeny or offspring trees will grow. By using

seed from many different trees, the probability of the offspring trees having good characteristics increases and ensures, that the trees can better adapt to environmental changes. A poor, but unfortunately very common nursery practice is to collect seed from just one, two or three easy-to-climb trees close to the nursery. If the seed is bad and does not germinate, the nursery crop could be lost. Collecting from just a few trees is also dangerous because it results in low genetic diversity. Trees with low genetic diversity are often more susceptible as a group to disease, or unable to adapt to changing environmental conditions such as drought. If an area is planted with trees from very few sources, in the future, our ability to choose the best seed sources and improve the characteristics of the trees is very limited.

Use seeds from an area as similar as possible to the area where you are planting. For example, seed from a mountainous region should only be planted in a mountainous region and seed originating from the lowlands will grow best in lowland conditions. For long-term genetic improvement though, seed from each individual tree is kept separately and tested in field experiments. The best trees are then selected to serve as seed sources for the nursery.

The principles of tree domestication are similar to those used in agriculture; maximize the quality of tree products, maximize tree growth rates, ensure the adaptability of species to the planting site, and maximize resistance to disease and pests. Selecting the best seed sources and managing the trees under optimal conditions achieve this (Jacnicke, 1999).

8.10.3 Seedling physical quality

No single characteristic determines seedling quality. Seedling quality is a combination of height, diameter, plant nutrition, health, root size and shape. Together, these characteristics determine how well the plant will establish itself in the field, and they affect the rate of survival. Height alone is often not a good predictor of how a plant will grow in the field. A good nursery practice is to judge seedling quality by several traits.

Many of these traits act together and influence one another. The goal of producing the best seedling is to optimize these traits while producing specifically what is needed for a particular site. You will need to talk to foresters and farmers to find out the most important desired

traits. For example, plants for dry, rocky soils need to be short and be produced in small containers, whereas plants for flooded sites (or) active pastures may need to be quite large.

Quality tree seedlings have the following characteristics:

- They are healthy, vigorously growing and free of diseases.
- They have a robust and woody (lignified) single stem free of deformities.
- Their stem is sturdy and has a large root collar diameter.
- Their crown is symmetrical and dense.
- They have a root system that is free of deformities.
- They have a dense root system with many fine, fibrous hairs with white root tips.
- They have a ' balance' between shoot and root mass.
- Their leaves have a healthy, dark green color.
- They are accustomed to short periods without water.
- They are accustomed to full sunlight.

The following examples demonstrate how these traits enable the plants to be more resistant to transport and planting stress, and how they improve seedling growth and survival.

8.10.4 How quality traits work together

'Sturdiness' is measured by the relationship between height and diameter. If two trees have the same height, and one has a larger diameter stem, then the latter is sturdier. A sturdy stem is less susceptible to transport and planting damage.

Stem diameter is often related to root size. Plants with large diameter stems often have large root systems. Diameter is a better predictor of root size than plant height.

A 'balanced' seedling has a small to medium shoot system and a large root system. The shoot loses water through the leaves and the roots compensate for this loss by absorbing water and nutrients. "Unbalanced' plants have too many leaves and too few roots. Balance refers to the mass or dry weight of the shoot and root, NOT to their length.

8.10.5 Assessing seedling quality

We do not need special equipment and it does not take long to survey seedling quality. When the seedlings are about 15 cm tall, choose at least 20 plants from each species for inspection. It is important to

sample randomly, that is, not to pick only the biggest plants or only plants from one bed. Try to sample plants from all parts of the nursery and from each bed in the nursery. Choose one or two plants from each end from the middle of each bed. Examine the plants thoroughly. 16 out of 20 plants (80%) should have the quality characteristics listed above. If fewer than 16 trees are of good quality, repeat this quality assessment at least once more about 1 month before the plants are taken to the planting site so that necessary improvements can be made.

A good nursery practice is to sacrifice a few plants to improve the quality of the total nursery production. One of the best ways of examining quality is to cut open the container to observe the root system of several plants; of course, these plants, must then be thrown away. Do not plant these seedlings afterwards, because when inspecting the root system, the fine root hairs will get damaged, and the plants will either die or become badly stunted.

8.10.6 Root deformities - the hidden curse

Root deformities below the soil line are the hidden curse in seedling production. They retard growth, cause the plant to lean or even fall over, and can result in the plant's death. Root deformities do not correct themselves over time, in fact, they become more acute as the tree grows.

The main root should be as straight as a carrot, or if there is no main tap root, the many smaller roots should branch out without any pattern or strong bends. If the roots are in knots or coiled, they will eventually strangle the tree or they may die, attracting insects and fungi that will damage the tree. There are two types of root deformities:

(1) Roots deformities caused by poor pricking out from the germination bed into the container

The deformities are generally within the first 10cm under the surface of the soil or at about a finger's length. Often, seedlings are squeezed into holes that are too short for the roots system. Roots are stuffed forcefully into bags or, while placing a seedling into a hole, the end of the root remains curled upwards. Because roots always want to grow downwards, they will bend back and grow into a 'knee' or even a complete loop. Nursery customers can check for these deformities by following the stem down with their finger. These plants should be refused because they will never grow well in the field.

(2) Roots deformities caused by the bag

Smooth plastic bags cause the principal root to coil or spiral along the walls or at the bottom of the bag or pot. This inevitably happens when plants are left in the nursery too long. However, it can also happen to plants that are only a few centimeters tall. Plants commonly develop roots before they begin shoot growth. So even plants with small shoots may have long roots that are coiled at the bottom of the bag. These roots should be cut off immediately before planting.

Table 8.1

Problem	Solution
Roots knotted or twisted from poor pricking out	Discard plants immediately. Next time, direct sow, or follow procedures for correct pricking out.
Roots coiled at the bottom of the bag	Cut roots with machete or prunes, before planting. Remove plants in good time from the nursery. Use root trainers.
Roots penetrating into the soil beneath bags	Lift bags and prune roots frequently. Remove the plants in good time from the nursery. Use root trainers on frames above the ground.
Multiple plants per bag	Remove extra seedling early, before they become very big
Plants with multiple stems	Discard-the cause may be poor genetic quality.
Diseases or insects	Isolate or burn any affected plants. Develop a plan for pest management.
Yellow or white leaves, or leaves with dark green or purple veins and light spots in between	Fertilize plants or use a richer substrate.
Large variation in plant sizes among plants sown at the same time	Check for patterns within the beds and throughout the nursery that can be associated with uneven shade or watering.
Plants grow slowly	Adjust light (try more or less), fertilizer or use a better substrate.

Source: Wightman (1999).

A good nursery practice is to regularly survey seedling quality to correct problems through appropriate nursery management. Some problems, and suggested solutions, are given in Table 8.1.

8.10.7 Keep the best, ditch the rest

In every population of trees, there will always be some plants of good quality and some of bad quality. On an average, 20-30% (and often even 50%) of the trees will be of poor quality. Thus, the nursery should always produce 20-30% more plants than needed to meet a given target. Nursery managers must accept that it is quite normal to throw away plants. Unfortunately, many do not; many people do not want to see their hard work thrown away, or they believe that the plants still might have a chance. These ideas are false.

A good nursery practice is to discard poor quality trees as soon as you detect them. They waste space and resources in the nursery, and can be a source of infection. The process of removing poor quality seedlings is known as 'culling'. It is a greater waste of hard work and money to maintain trees of poor quality in the nursery and in the field, than to throw away poor quality trees in the nursery.

Variable plant growth in the nursery is carried over to the field. A weak plant will never catch up with others that were strong when planted out. A poor, but unfortunately common, nursery practice is to select the best trees for planting, but then leave the bad ones in the nursery. These are then given to the next unsuspecting customer. This is very unfair to the customers. Only the best quality trees should leave the nursery, the others should be thrown away at that very moment. A plant that is not considered good quality does not suddenly become better when the best ones have been planted.

Another poor, but unfortunately common, nursery practice is to leave plants in the nursery from one production year to another. These are usually the left-over plants that no one wanted, but the next planting season they are overgrown and have severe root deformities. If plants grow very slowly during the year and remain in the nursery more than one season, throw these ones out, and try adding more compost to your substrate, or allowing your plants more sun.

8.11 SEED PRE-TREATMENTS AND SEED STORAGE

If seeds are enclosed in a fleshy fruit, remove as much as possible

of the flesh with a knife, wash off the rest under water, and plant the seeds immediately. Fruit flesh attracts insects and fungi, which may damage the seed, so it's important to plant the seed as soon as you can. For seeds in a seed pod, such as a bean, let the pods split open naturally by laying them in a semi-shaded place. Similarly, for other fruits with a woody coating, drying them in semi-shaded or gently cracking should open them and let you collect the seed. Some sun is good, but be careful not to overheat, which might kill the seeds.

A good nursery practice is to pre-treat the seeds, if they take more than a week to germinate. You will save time and resources by pre-treating seeds. Faster production time in the nursery means lower nursery costs and may also allow the farmers to plant the seedlings during the best planting times. If you are unsure how long the seed will take to germinate, sow some before you sow all of the seeds to find out. If most of the seed germinates well with the first treatment method, then that is probably sufficient. If not, try the next treatment method and so on until you obtain the best germination rates (Janicke, 1999).

The seeds contain two parts; an outer protective coat, and the inner embryo that develops into the plant. Germination begins when water penetrates the seed coat and the seed swells. When seeds swell, plant them immediately. Discard seeds that float; they probably have air pockets caused by insects or dead embryos. Always use 2-5 parts of water for each part of seed (e.g. two to five tablespoons of water for one tablespoon of seed). Change the water every 12 hours to remove chemicals that may also slow down germination.

Do some tests to see the best orientation for sowing the seeds. This is especially important if the shoots or roots are twisted when they emerge from the seed, which is common in mahogany and mango. In southern Mexico, the common way to sow mahogany seedling is with the wing pointing up. But in one nursery, the manager noticed that the best way to plant was with the wing pointed down. In Puerto Rico, it is recommended by a forest research station that seed be planted flat. In such cases, you should do trials of all three methods and see what works best under the conditions you have (Wightman, 1999).

8.11.1 Four basic seed pre-treatments

1. Cold water treatment: Soak seeds in cold water for at least

12 and up to 48 hours. You can also try soaking the seeds in water during the day, and leaving them to dry at night.

2. Hot water treatment: Boil water in large pot, remove from heat and cool for 10 minutes. Add seed to water and let soak for up to two days.
3. Boiling Water treatment: Boil water in a large pot, remove from heat, add seed and leave for two minutes. Pour off the hot water and replace with cold water. Soak the seed for up to two days.
4. Mechanical: It is important not to damage the embryo or the part of the seed where the root will emerge (usually an indented place or a pointed area). Nick the seed with a knife, crack it with a stick, or scratch its surface on a concrete floor, or with sandpaper. For small seed, place in a jar lined with sandpaper facing the inside of the jar, and shake vigorously. It is not necessary to completely remove the tough outer seed coat just crack it so that water can enter the seed and trigger germination.

A good nursery practice is to sow the seed immediately after collecting, or store correctly if necessary. You should plan ahead and have containers filled, so that seed can be sown without delay. If you must store seed before sowing, make sure it is kept well ventilated in a cloth or mesh sack, or in clay pots. If a refrigerator is available, you can use plastic bags or containers.

Only clean, dry seed should be stored. Hang the sacks from a pole so that air can circulate all around them. Keep the seed in a cool dry place, out of direct sunlight. A fungicide may help reduce fungus attack. Mothballs or other strong-smelling materials like cedar wood may also help reduce insect attack. Check seed regularly for signs of decay, insect or rodent damage.

The length of time that seed can be stored varies greatly between species. Some seed can be stored for many months, while other seeds lose their viability. If the seed has been stored for more than one month, a good nursery practice is to test the germination rate to see if the seed is still good. A poor, but unfortunately common nursery practice is to

sow old seed in many containers, without knowing if it will germinate-you might be wasting time, labor and resources. Sow 100 seeds in a shady germination bed and water normally. Count the number of seeds that germinate, and this will tell you how many you need to put into each container to achieve one plant per pot. If for example, only 25 out of 100 seeds germinate, sow four in each container (Wightman, 1999).

8.12 SEED GERMINATION

The most important factor for good germination is constant humidity around the seed. Seeds can be covered with sieved soil, sand rice hulls or pine needles, to keep them moist. A light material allows the tender roots and shoots to emerge without hindrance. The substrate should be moist, but not soggy; excess water should drain off. It is often recommended that you plant large seeds deeply and small seeds close to the surface. While this is usually sensible, if the substrate dries out quickly, or water is not always available, you will need to plant the seeds deeper. If the water pressure in the hose is very high, it may wash the seeds out, so again, plant the seed deeper. A good nursery practice is to carefully control the light, water and shade conditions during initial seedling growth. Shade helps retain humidity and prevents new leaves from scorching. This can be achieved in a seedbed as well as directly in the container (Antonio et al, 1985).

The substrate should not receive additional fertilizer because this could increase the risk of diseases such as damping-off. Germinating seedlings generally receive all nutrients they require from the cotyledons (or in the case of palms, from the first leaf) that are formed inside of the seed. Thus, substrate-like sand, which does not contain fertilizer, is generally a good germinating medium. Damping-off is common with small seedlings and is recognizable as either decayed seed or, more frequently, decay around the stem at the soil line. The leaves of the seedling droop as though they need water, although the substrate is wet, then the stem appears "pinched" and brown near the base. Eventually, the seedling falls over at the soil line.

Damping-off is caused by fungi which can be present on the surface of the seed in the substrate. Seed can be sterilized by immersing it for 30 minutes in a 10% solution of Clorox (1 tablespoon of bleach

plus 9 tablespoons water). Hydrogen peroxide, a common antiseptic available at the pharmacy, is also an effective seed sterilant. Its advantages are that it is less toxic than bleach, and it can increase germination because it softens the seed coat allowing water and oxygen to enter more easily. Seed is soaked directly in the antiseptic for up to four hours. With both bleach and hydrogen peroxide, some experimentation may be necessary to find the most effective solution strength and soaking time. A 30 minutes soak with hot (just too hot to touch comfortably - definitely not boiling) water also works well on seed. The substrate can be sterilized by wetting the area well with water then covering the area with a black plastic sheet for several days while it stands in abundant sunshine. The heat kills bacteria, fungi, and weed seeds. You can sterilize sand by washing it several times until the wash water appears perfectly clear (Technical Bulletin, World Bank, 1991).

When deciding whether sterilization is necessary, first determine whether seedling growth is being harmed by something living in the soil by carefully examining the type of damage to the plant. Is the damage at the soil line or at the roots? If yes, then sterilization may be necessary. Test the different methods to determine if seedling growth really improves. A good nursery practice is to carefully recognize the type of damage on the seedling, and control the specific problems with the right method for that particular pest. Remember that sterilization of the substrate can also kill beneficial fungi, bacteria and insects. Certain bacteria and fungi are necessary to break down organic matter or help plants to absorb nutrients better. Many insects too are useful because they eat other insects that eat plants.

8.12.1 Some of the common problems with seedbeds are that:

- Pricking out almost always results in root deformities
- When plants are left in the seed bed too long (which often happens), they produce long roots that are easily damaged or twisted when pricked out
- Many seedlings suffer a 'shock' when they are transplanted from seed beds. Their growth is slowed for 1-4 weeks before they begin to show visible new growth
- Pricking out is often done by staff with little nursery

experience, and even people with experience often prick out incorrectly, and

- Paying people by the number of plants pricked out in one day gives no incentive to prick out correctly.

8.12.2 When to direct sow seed

Careful control of water, light and nutrients is required during germination and during the first few weeks of seedling's growth. Directly sowing the seeds in the container saves time, labor and money, because the extra step of preparing a seedbed and transplanting is eliminated. Even if it takes little longer to plant small seed directly in the containers or if they have to be moved and resown, this is easier and cheaper than pricking out. Direct sowing allows undisturbed seedling growth and this reduces stress for the seedling. In a well-managed nursery, seedlings can almost always be directly sown! (Wightman, 1999).

When you are directly sowing, follow these good nursery practices

- Use only fresh and ripe seed
- Pre-treat seed, if necessary, to speed up germination
- Prepare containers and shade in advance
- Mix small seed with sand or rice hulls, or use a bottle with a screen top (like a salt shaker, but larger), to make dispersing it easier
- Test seed for viability before sowing. If less than 70% germinate, sow more seed again in the bag. Throw away any extra seedlings in each pot. This is a small price to pay to avoid root deformities.

8.12.3 When to use seed beds

Depending on the conditions in your nursery, including the tree species, number of plants produced, and labor availability, a combination of direct sowing and use of seedbeds may be your best way of operating. The use of seedbeds is NOT recommended simply in order to ensure every container has a seedling. Seedbeds can be used:

- To select seedlings of uniform size and development for transplanting. Only plants of the same age should be compared when judging plant quality. When seed germination is highly

erratic, seedlings should be transplanted in groups of the same age. Seedlings should be pricked out in groups of even ages so that later they will not be compared with plants of a different age class.

- When seed is old, or when the germination is low or unknown. Use as seedbed to test seed viability before filling too many containers and wasting resources.
- If seed does not store well (that is, if it is 'recalcitrant').
- If containers are not available, or not filled in time to use; Seedbeds can be used until the containers are ready.

8.12.4 Types of seed beds

There are two types of seeds beds, temporary and permanent. Temporary seed beds include any tilled bed of soil. Alternatively, seeds can be germinated between bags of jute or sheets of newspaper that are kept constantly wet, but not soggy. The advantage of using newspaper or a similar material as opposed to planting in a bed of sand or soil is that you can easily check the stage of seed germination and prick the seedling out as the taproot emerges. It is not necessary to wait until the seedling grows 15 cm and produces its first true leaf, and in fact that's not a good idea, because the older, better-developed seedlings are more susceptible to damage when pricked out.

Plastic bags filled with a sand and soil mixture are common. The bag can be closed initially to provide shade and a humid microenvironment. Small seed lots can be germinated, and the substrate can be easily loosened to remove the seedlings. Another advantage of these bags is that they can be moved directly to the rows of containers where the seedlings will be planted.

Permanent seed beds are commonly constructed with cement blocks at 1 m or more heights and 1.2 m width for working comfort and efficiency. They are filled starting at the bottom with stones, then gravel, then soil or sand. A common practice is to prepare wooden boxes with a fine wire mesh bottom and fill them with sand. The boxes are placed on table in a greenhouse or under a roof. The tables are also covered with fine wire mesh to allow good drainage and aeration. Frequent watering is necessary because the sand does not retain much

water. Creating the proper germination conditions in containers, and pricking out correctly, are more important than constructing tidy, permanent germination beds (Hibbered, 1991).

8.12.5 How to prick out correctly

Even when pricking out is done very carefully as described below; it is still very hard to do it correctly, especially when thousands of plants must be transplanted. Only those who are trained in correctly pricking out should attempt it. Unfortunately, many people who have pricked out in the past have done it incorrectly. Close supervision and revision of the plants is necessary in order to avoid root deformities. Always open a few containers after a few days to check that it has been done correctly (Technical Bulletin, World Bank, 1991).

Good pricking out practices

- Throw away any seedling that appears sick or deformed.
- Transplant when the tap root emerges or seedlings are still small (5 cm), before secondary roots are formed.
- Water the bags well, one night before you prick them out, so that water penetrates to the bottom of the seed bed.
- Ensure that the area where the transplanted seedlings will be kept is well shaded before you begin pricking out.
- Water the seedlings 24 hours before, and one hour before, pricking out.
- On days with strong sunshine, prick out in the early morning or late afternoon.
- Use a shovel or stick to gently loosen the soil around the seedlings.
- Remove seedlings by grasping their cotyledons or lower leaves—do no lift them out by the stem.
- Put seedlings in water as soon as you take them from the germination bed.
- Prepare planting holes with a stick and ensure they are sufficiently wide and deep.
- Clip long or very branched roots to ensure they are pointed downwards.

- Gently pull the seedling upward after placing it in the hole, to straighten out roots.
- Pack the soil against the roots, starting at the bottom of the hole.
- Water the plants immediately after transplanting, and again when they wilt.

Poor but unfortunately common pricking out practices

- Waiting until plants are large and have long roots.
- Pricking out plants into dry soil and then watering them.
- Constructing shade after pricking out is done.
- Pricking out in direct, hot sunlight.
- Transplanting damaged seedlings.
- Removing seedlings by grasping the stem, as this may permanently damage the flow of water.
- Carrying seedlings in your hand or on a plate without water.
- Preparing the holes with a finger-the hole will usually be too small.
- Allowing roots to bend upwards when inserting them into the hole.
- Leaving air pockets around the roots - the plant will die.

Summary of sowing and seedling germination

Whenever possible, direct sow of seed into containers, will avoid root deformities. Controlling the germinating environment and correctly pricking out are more important than constructing fancy seed beds.

Good nursery practices

- Sow seed as soon as possible after harvest.
- Pre-treat seed, if it takes more than a week to germinate.
- Test old seed before planting to know if it will still germinate.
- Carefully control the light, water and shade during seedling growth.
- Sow seed directly in the container.

Poor, but unfortunately common nursery practices

- Expending a lot of effort to build fancy seed beds.
- Careless pricking out resulting in damaged plants with root deformations.
- Leaving seedlings in the germination bed too long. □□□

9

BAMBOO PROPAGATION TECHNOLOGY

Bamboo plantations can be raised by the following methods:

1) Direct sowing of seeds
2) By culm with roots and rhizome
3) By the stock with roots and rhizome
4) By rhizome with roots
5) By offset planting
6) By the cutting of culm
7) By branch cutting
8) By tissue culture

9.1 DIRECT SOWING OF SEEDS

9.1.1 Seed characters

Possibilities of raising bamboo plantations from seeds are not always practical because of the unusually long seeding cycles. Except in the case of *Melocanna baccifera,* seeds of most of the commercially important species of bamboo resemble grains of paddy (or) wheat and are light in weight. Seeds for direct and nursery sowing should be obtained direct from the forest. The seed may be collected either on the

ground previously cleared (or) on a cloth spread around the culm, by shaking the culms. The best time for collecting the bamboo seeds is between the months of February and July consequent to the flowering. The number of seeds per kilogram varies from 75,000 to 1,05,000. The bamboo seeds remain viable for short periods, with the initial viability is being good, the seeds rapidly lose germination vigour. The longevity of seeds varies from species to species but they are generally viable upto 1-2 months, although the period can be increased under controlled storage conditions. Seeds of *Bambusa tulda* stored in a desiccator over silica gel maintained their viability even after 18 months (Banik, 1987). By storage of seeds under suitable temperature and moisture, the longevity of *Dendrocalamus strictus* seeds could be extended upto 34 months (Gupta and Sood, 1978). The viability of seeds varied from 30-35 days for *Bambusa tulda,* 55 days for *Dendrocalamus longispathus*, 65 days for *Bambusa arundinacea.*

Seeds of *Thyrostachys siamensis* can be stored for about 27 months under controlled conditions (Anantachote, 1985). Seed viability can be extended by reducing the initial moisture content before storing, which helps in maintaining viability up to 9 months. Seed samples stored at room temperature lost their viability within 21 months, in comparison with seeds stored for 27 months under low temperature such as in the cold room (2-4 °C) and deep freezer (-5 °C), and could maintain a high percentage of viability (89.2 - 92.5) and were able to germinate within 3- 4 months (Ramagarangasi, 1988).

Seeds should be given pretreatment before sowing, i.e. normally soaking in water for 48 hours. Bamboo germinates generally within 5-10 days of sowing and the seedlings attain 1-leaf stage in 7 days. Percentage of germination is higher when seeds are sown directly in polythene bags rather than in nursery beds.

9.1.2 Direct sowing

For direct sowing, the soil should be dug upto a depth of about 10-15 cm, (or) deeper in case of poor soils, either in line 3 m apart, (or) in patches 3m × 3m (or) 4.5 × 4.5m apart and cleaned of all weeds. Seeds, after having been soaked for 48 hours before sowing are dibbled in beds at the plantation site and slightly mulched. The resultant plant is

kept clean weeded for the first 2 (or) 3 seasons. 1.25 kilogram of seed per hectare will suffice for widely spaced patch sowing and about 11.5 kg for line sowing. Though direct sowings are an easy method, they are generally neither practicable nor desirable owing to shortage of seed, the necessity of continuous weedings till plants are well established and the liability of destruction by seed eating birds and rodents.

9.1.3 Transplanting

As direct sowings in lines are often liable to fail due to relatively (i) uneven germination, (ii) slow growth of resultant plants, and (iii) exposure to animal damage etc., the more usual procedure is to raise plants in a nursery bed for transplanting entire plants. For this purpose the nursery site should be located well within the planting region and near an adequate supply of water.

At first the seedlings look like grass, whippy shoots appearing after a few months. Great care is required in planting out bamboo seedlings, which are liable to wither if the roots are exposed to the sun. Planting should be done as quickly as possible, before commencement of monsoon season. Transplanted seedlings are irrigated two hours regularly both in the morning and evening. Weeds are removed from the plantation area as and when required. After one year, the plantation should be adequately irrigated at 15 days interval. Care must be taken to avoid water logging and protect against rodents, grazing and browsing animals.

9.2 BY CULM WITH ROOTS AND RHIZOME

In this method, the new young ones sprouted in the same year (or) the previous year should be used. Although large-size culms are preferable able and the small-size ones also can be used. Leaving the branches with several nodes, the culm with branches of upper part is removed. The rhizome of the culm should be yellowish, young, vigorous and bearing good buds. Old rhizomes should not be used, for they are lacking the buds that develop into culms. The length of rhizome is 40-60 cm in length with about ten nodes and buds. Fibrous roots on both culm and rhizome must be left. The rhizome should be cut carefully with a saw; cutting with a hatchet will cause damages to the buds.

9.3 BY STOCK WITH ROOTS AND RHIZOME

In this case the culm is branched and its length is about 30 cm. The procedure is the same as in the above method.

9.4 BY RHIZOME WITH ROOTS

Rhizome without culms are cut 50-60 cm long with about 10-15 nodes and their roots. The 2-3 year old rhizomes with roots are most satisfactory, but over 5 year old rhizomes are entirely unsuitable. This method is recommended for transplanting to distant places. In this case, they are wrapped with sphagnum moss and covered with vinyl sheets after the soil is washed away. Usually, they are first laid in the nursery bed 20 cm deep and covered with soil. They are transplanted next spring, as new culms begin to grow. This method is applicable to monopodial type.

9.5 BY OFFSET PLANTING

This is the good method of vegetative propagation of clump - forming bamboo species in which success has been achieved. One year old culms which are ready to sprout within the year are cut off with short rhizomes. The culm should be about 40-50 cm in length. The success of this method depends in part on the vitality of the rhizome stock used and the time of the year when it is planted. If the rhizomes are taken from young healthy stock and planted immediately at the break of rain success can be expected. But if the rhizomes are taken from old stock and planted much before the rains, complete failure may result. The weather of the year must also be an important factor.

9.6 BY CUTTING OF CULM

This method, however, has a limited use because of the limited availability of the planting material. Rooted culm cuttings can be successful with most bamboo species. The age of the culm and the period when these cuttings are put out for rooting are important considerations. The two year old culms and spring season have been found to give best results.

However, a method of vegetative propagation using culm cuttings has been standardized at the Kerala Forest Research Institute (KFRI). This involves treatment of culm cuttings with growth regulating substances for including root formation. The method was tested for (*Bambusa arundinacea, B. balcooa, B. polymorpha, B. ventricosa, B. vulgaris, Dendrocalamus brandisii, D. hamiltonii, Ochlandra scriptoria* and *O. travancorica*) 12 species of economically important bamboos and

was found successful. Large scale multiplication of superior varieties is possible by this method. When out planted, plants raised from cuttings develop to clumps much faster than seedlings. This portion describes the practical steps involved in propagation of bamboo through culm cuttings.

9.6.1 Collection of material and preparation of cuttings

Extract 2 to 3 years old culms from healthy culms by cutting just above the first node during March-April. Trim the leaves and side branches. Care should be taken not to injure the auxiliary buds while removing leaves and branches. Transport the culms to nursery site as quick as possible. Maximum care should be taken to prevent drying. This can be done either by wrapping in moist gunny bags (or) embedding in boxes containing moist sawdust. Two-noded cuttings (a cutting with two nodes leaving about 5-7 cm on either side of the nodes) must be prepared using a sharp knife (or) saw. For bamboos with thin walls use of a saw is advised to avoid splitting of the cut ends. Make an opening (about 2 cm in length and 1 cm in width) or drill two holes (about 7 mm diameter) in the centre of the inter node.

9.6.2 Treatment for root induction in cuttings

10 gram of NAA (1-Napthalene acetic acid) BDH, Loba Chem (or E. Merck), is dissolved in 250 ml of ethyl alcohol (90%) in a container by stirring the solution gently and add water to make up to 100 liters. The solution is mixed thoroughly by stirring. The final concentration of NAA will be 100 mg/1 of water (or) equivalent to 100 ppm. This solution is sufficient to treat 1000 cuttings. About 100 ml of the solution is poured to the culm cavity. To avoid spillage, use a wash bottle to pour the solution through the drilled holes. The holes were closed by rapping a drying with a polythene strip (60 cm × 6 cm). Ensure that the polythene wrapping is tight so that the solution does not leak out. The cuttings were kept horizontally with the opening facing upwards. For bamboos with narrow culm cavity like *Dendrocalamus strictus* the treatment is given by dipping the basal portion of the culm cutting in solution of NAA for 24 hours. After extraction, the culm cuttings should be treated with NAA as quickly as possible (preferably the same day). If the planting site is far away and there is unavailable delay for planting, the treated cuttings can be presented up to three days by keeping in moist sawdust.

9.6.3 Preparation of nursery and planting

Raised nursery beds of 10 m × 1 m is prepared and filled with a mixture of soil and sand (3 : 1). One weak prior to planting, drench the nursery bed separately with the insecticides, Aldrin and the fungicide, Bavistin to prevent termite and fungal attack. For each bed, use 40 litres of 0.015 % (9.1). Aldrin prepared by adding 0.5 ml of Aldrex 30 EC per litre of water and 30 litre of 0.05 % (9.1). Bavistin is prepared by adding 1 g of bavistin 50 WP in one litre of water. The treated cuttings were placed horizontally (the opening facing upwards) across the nursery bed. About 50 - 60 cuttings may be conveniently planted on a raised nursery bed of 10 m × 1 m. The cuttings were covered with a thin layer (2 - 3 cm) of soil.

9.6.4 Nursery management

Nursery beds must be provided with a thatch to protect the cuttings from direct sunlight, which may be removed at the onset of monsoon. The beds should be watered regularly in the morning and evening with 30 to 40 litres of water per bed at each watering. Care should be taken to avoid water logging. The sprouts after one month are treated with 0.01 % a.i of Bavistin to avoid fungal attack. If necessary, farmyard manure may be applied to increase the vigour of the sprouts.

9.6.5 Transplanting

Rooted cuttings can be uprooted and transplanted to the field during (June - July) (after about 4 months). If cuttings are sprouted and rooted at both the nodes, cut carefully at the middle of the cutting to get two plants.

9.6.6 Precautions

The collection of culms from clumps which are likely to flower in the near future is to be avoided, because new clumps developed from such cuttings will also flower and perish along with the mother clump. The year in which the clumps are likely to flower can be found out by checking the previous flowering record from the area and the flowering cycle of the species.

9.7 By branch cuttings

In this method, branch cuttings from the bottom, middle and top portions of the healthy culms are taken from the clump. With a sharp

knife, the branches are cut at their basal portion, the leaves and side branches are removed and cuttings with two internodes are prepared. The cuttings are immediately transferred to the nursery. A natural rooting medium (mixture) is prepared by mixing rice husk, dried powdered cow dung, charcoal and sandy soil in equal proportions. The mixture is filled in black polythene bags of 45 cm height. The cuttings are placed in a thatch to protect from direct light. They are regularly watered in the morning and evening. The cuttings sprout within 20-30 days after planting and root development, can also be observed within this period. Rooting efficiency is better in the samples taken from the bottom region. The branch sprouts start to develop from that region. The rooted cuttings are transferred to the soil in August. July and August are suitable season for the vegetable multiplication of bamboo using branch cuttings. The method has the following advantages: -

(i) It is simple and can be adopted by the farmers.

(ii) There is no need of costly chemicals like hormones.

(iii) A large number of propa gules can be obtained without cutting the culm.

9.8 BY TISSUE CULTURE AND MACROPROLIFERATION

Large scale production of bamboo seedlings for raising bamboo plantation is hampered by the long vegetative cycle and death of the flowered clumps, coupled with low speed viability. Although planting stock can be produced by vegetative propagation, the synchronous flowering of the vegetatively propagated clumps and parent clumps leads to the death of the entire plantation. At this juncture tissue culture assumes great importance to replenish the acute shortage of planting stock as the cultures can be maintained in juvenile phase for long durations.

9.8.1 Tissue culture of Bamboos

The concept of tissue culture is borne out of the fact that, every cell in a plant is capable of regenerating into an entire plant, thus making it possible to regenerate innumerable number of plants from a single bud. A number of protocols are published for multiplication of bamboo. All the available protocols have been tested and viable protocol for mass multiplication and transfer to field have developed been at plant Biotechnology Division of Forest Genetics and Tree Breeding,

Coimbatore. Protocols for multiplication have been developed for *Dendrocalamus strictus, Bambusa arundinacea, Dendrocalamus asper* (edible bamboo), *Phyllostachys edulis Dendrocalamus giganteus* and *Bambusa polymorpha.*

9.8.2 Collection of bud materials

The single nodal buds from identified phonotypes (or) axillury buds from seedlings/young plants can be taken as the basic material for culture. The time of collection of bud materials from the mature culm is critical. They are collected at the time when the buds start swelling. In case seedlings material is used as explant, nodal, portion from one month old seedling are preferred for multiplication.

9.8.3 Sterilisation of explants

The buds are washed thoroughly with running water and sterilised with 0.1 % Sodium hypochlorite for 5 minutes, washed with sterile distilled water and with 0.1 % Mercuric chloride for 5 minutes and all traces of the sterilant removed by rinsing with sterile distilled water. In the case of nodal explants from mature culms more rigorous sterilisation is advocated.

The entire operation is carried out in the laminar flow chamber to maintain aseptic condition. The explants are initiated in Murashige and Skoog medium supplemented with 0.5 mg/ltr Benzyl Amino Purine. The cultures are maintained at a photoperiod of 12 hrs dark and 12 hrs light with cod fluorescent lamps (100 μ mol m^{-2} s^{1}).

9.8.4 Preparation of media

The buds are initiated in a medium containing essential nutrients for growth. Basic bamboo culture medium ideally suited for multiplication is given below.

9.8.5a Bamboo culture Medium (Stationary liquid culture) developed at Plant Biotechnology division of Institute of Forest Genetics and Tree Breeding

Compounds	mg/ltr
Ammonium nitrate	1650.00
Potassium nitrate	1900.00
Calcium chloride	440.00

Magnesium sulphate	370.00
Potassium dihydrogen phosphate	170.00
Potassium iodide	0.83
Boric acid	6.20
Manganese sulphate	22.30
Zinc sulphate	8.60
Sodium molybdate	0.25
Copper sulphate	0.03
Cobalt chloride	0.03
Ferrous sulphate	27.84
Ethylene diamine tetra acetic acid	37.30
Myo-inositol	100.00
Nicotinic acid	0.50
Pyridoxine	0.50
Thiamine HCl	0.10
Glyane	2.00
Sucrose	30000.00
Benzyl Aminopurine	0.50

The above chemicals are weighed accurately and dissolved in 1 liter double distilled water. The pH of the medium is adjusted to 5.0. The medium is then dispensed into jars covered with suitable enclosures and sterilized in the autoclave for 20 mts at 15 lbs pressure. The media may need modification depending on the physiological status of mother plants at the time of bud collection. For explants derived from seeds modification is not necessary.

9.8.5b Sub culture

Within one months of culturing, the buds start producing multiple shoots. Regular sub culturing is done every 20-25 days in the same medium. Within 20 days, about 20-30 shoots are produced. These are further sub cultured with three shoots per flask.

9.8.6 Rooting and out planting

Much of the shoots on prolonged culture are rooted in the same medium. 90% of the plants root successfully in MS half strength medium

supplemented with 0.1 mg/ltr Indole Butyric acid. Micro rhizomes are also induced under in vitro condition so that plantlets become hardy. This also ensures high survival rate when transplanted in polybags. The rooted plants with microrhizome are then transferred to a medium containing sand, soil, vermiculite in the ratio of 1:1:1 and kept in poly globule for hardening for a period of two weeks. If required, during this period 0.1% Bavistin is sprayed to avoid fungal attack. Subsequently, the polyglobutes are opened and the plantlets kept in shade house for a period of one month and then transferred to the field. While the plantlets are kept in the shade house, Hoagland's solution is fed to the plants to enable them to rapidly gain height and dry matter. Within a month the hardened plants are transferred to the field.

9.8.7 Transplanting

The seedlings are planted at 6m x 6m spacing with a total of 250 seedlings per ha. The transplanted seedlings are irrigated two hours regularly both in the morning and evening. Weeds are removed from the plantation area as and when required. After one year, the plantation is adequately irrigated at 15 days interval. Care should be taken to avoid water logging and protected against rodents grazing and browsing animals.

9.8.8 Production of culms

All transplanted seedlings begin to produce rhizomes. From these rhizomes lateral culms will emerge which are the chief causatives for the total biomass yield. The number of culms developing from the rhizome totally will constitute a clump. The productivity of bamboo is assessed by the number of new culms produced annually. At a given site the production of new culms is mostly dependent on the culms of the previous year, the degree of congestion and the clump age.

9.8.9 Macro proliferation

In order to increase the planting stock before transfer to the field, macro proliferation is practiced. Four to five months old plants in the nursery developed with the above procedure has good rhizome system. These plantlets in the nursery develop five (or) six tillers at four to five months period. These tillers are separated along with a small piece of rhizome and roots. These propagules attain the size of field plantable saplings within four months (or) they can be further multiplied through macro proliferation.

Thus by this technology a large number of identified planting stock can be made available. Using this technology one bud can be made to produce three hundred plants in three months which can further be multiplied on a larger scale. Essentially the approach is same for all the species of bamboo, viz., *Dendrocalamus strictus, Bambusa arundinacea, Dendrocalamus asper* (edible bamboo), *Phyllostachys edulis, Dendrocalamus giganteys* and *Bambusa polymorpha.* Varying the cytokinin concentration and effectively subculturing within a period of 20 - 25 days would help in continuous production of propagules with high multiplication frequency. The propagule production is limited by manpower availability for subculturing frequency and space availability in the tissue culture laboratory and rapidity with which it can be transferred to the field. Several thousands of prop gules can be produced by careful planning and anticipating the limitations. It is advisable to obtain the total planting stock requirement, at least a year in advance and work - back the multiplication strategy.

Plan for mass multiplication of Bamboos

Seed from identified phenotype

↓

Aseptic germination

Identified Phonotype ——————— ↓

Explant (single node)

↓

Explant in culture medium

↓

Multiple shoot formation

↓

Continuous culture for multiplication

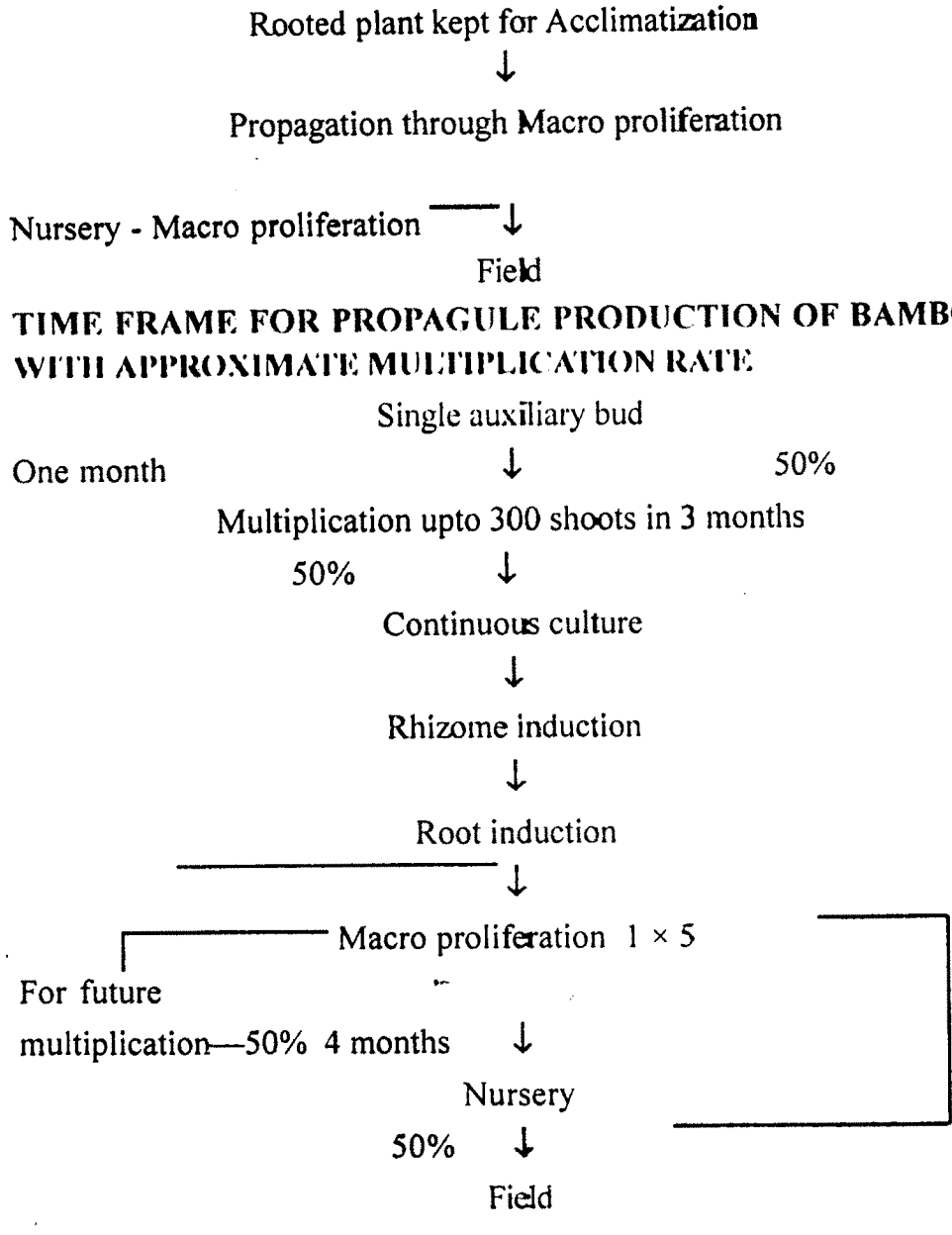
↓

Rhizome induction

↓

Root induction

↓



TIME FRAME FOR PROPAGULE PRODUCTION OF BAMBOO WITH APPROXIMATE MULTIPLICATION RATE

9.8.10 Season of planting

The time of planting is a most decisive factor in the ultimate success of the plantation. Planting work must be undertaken immediately after the first showers of the monsoon. If it is rhizome planting, when the buds on rhizomes slightly show a sign of swelling, it is the best time for the selection of good shoots. Caution must be taken in transportation of such rhizomes for prevention of injury of the buds. Suitable irrigation is recommended when bamboos are planted in mountain area. The new

shoot that has sprouted in the same year may be planted very carefully with rhizomes during the rainy season in and after June. In the tropical regions, the rainy season from spring to summer is the optimum season for planting.

9.8.11 Number under planting

When the soil is fertile or the species is a type of large - size culms, plantation is carried out less densely than in the case of poor soil or of the species developing culms of small size. Generally, the number to be planted is 300 - 500 per ha (space 4 - 6 m). So, before planting the soil analysis is to be carried out, to supply the nutrient status in the soil.

9.8.12 Method of planting

Instructions for planting are as follows;

(i) The junctions of culms and rhizomes should not be injured.

(ii) The bamboos should be planted, after being dug up as soon as possible. For the transportation to a distant place, rhizomes are cut with roots but without the culms and then wrapped with sphagnum moss after the soil has been rinsed away.

(iii) After planting, they are irrigated and fertilized. The direct contact of fertilizers with the bamboo roots should be avoided. The fertilizer is applied in the following proportion: per ha. 200 kg of 15:15:15 N.P.K fertilizer is sufficient for increasing the production of culms.

(iv) On a sloped land, rhizomes are planted in such a way that the buds come out on the upper side of the slope.

9.9 GUIDELINES FOR MANAGEMENT

Traditionally, bamboo has been referred to as minor forest produce. However, the status of bamboo has changed considerably and it is rapidly emerging as an important plant group in many forestry programmes. During the past few decades, several Asian countries have embarked on large - scale cultivation of economically important species. The important guidelines for raising and management of bamboo are discussed here.

Although the raising of bamboo plantation by vegetative methods is found successful, the availability of required propagating material is scarce. Seeds possess short period of viability and the procurement of

seeds is also difficult. So, the seedlings obtained from tissue culture methods are used. The large sized polythene bags 20cm x 30cm are filled with clean soil, sand and manure in the ratio 2:1:1. About 15 to 20 plants are planted in each polythene bag. The nursery is adequately irrigated and care should be taken to avoid over saturation. Seedlings are kept in polythene bags for one month. Nursery beds were provided with a coconut thatch to protect the seedlings from direct sunlight.

Each polythene bag contains 15 to 20 seedlings. The number of rhizomes may vary from 4 to 5. These set of rhizomes are not singled out or sorted out, but the entire thing in one polythene bag is planted in the field.

The seedlings are removed from their polythene bags carefully and transplanted to 45cm×45cm×45cm pits in the fields at a spacing of 6m×6m. One week prior to planting, the pits are treated with 0.01% aldrex and 0.05% bavistin to prevent termite and fungal attack respectively. The planting should be completed before the monsoon fully sets in.

To provide better initial growing environment to the seedlings, the upper halves of the pits are filled up with a mixture of 25 gram 15:15:15 N.P.K fertilizer per pit, while lower halves are filled up with the original soil. Protection against damage by rodents, grazing and browsing animals is to be carried out. The watering is done, but over watering is avoided.

The transplanted seedlings produce rhizomes, which develop new rhizomes that produce lateral culms, which are the chief causatives for the total biomass yield. The number of culms developed from the rhizome totally constitute a clump.

At a given site the production of new culms is dependent on the culms of the previous year, the degree of congestion and the clump age. The average annual recruitment of culm generally increased year after year. The culms produced during first year are shorter in length and smaller in diameter, but culms from subsequent years will be longer in length and bigger in diameter.

The rhizome development is not peripheral as generally believed. Rhizomes may develop is any direction and the culms may appear anywhere in the clump provided overhead light is available for the

emergence of the culm. It is only in congested clumps that the new culms appear to grow at the periphery. The new culms can even be seen in the middle of the clump.

New bamboo culms are produced each year. Older culms should therefore be harvested every year. Culms older than two years take little part in the growth of the new culms. Retention of culms older than two years is therefore not needed for the production of new culms. Culms older than three years are fully mature are desired for use. The following rules should therefore be applied for getting high productivity of the desired quality of culms:

(a) All bamboo culms three years older should be harvested.
(b) Harvesting should preferably be done each year.
(c) Where congestion has already set in the congested culms must be removed even if it leaves only the current year culms.
(d) Where the young culms are twisted from the top they should be cut, so that new culms grow freely.
(e) No gelling operations should be carried out from July to October.
(f) Mounding (or) heaping earth around the bamboo culms should be carried out after every felling of culms.
(g) Bamboo clump should in no case be clear felled. The clear felled clump generally degenerates into a bushy form.

The above mentioned siliviculture and management practices can be used as guidelines for taking up large scale plantations on suitable site.

A protocol for Micropropagation from seedling explant.

1. Collect fresh viable seeds.
2. Place these seeds in water, and treat them with 5-10% (W/V) mild detergent solution.
3. Shake vigorously and leave it under running water for one hour.
4. Wash the explants so as to free from Treatment solution.
5. Sterilize the plants in 0.1% (W/V) $HgCl_2$ under the laminar Airflow Chamber for 5-10 minutes.
6. Wash the seeds in sterile distilled water for 2-3 times.
7. Inoculate the seeds in a freshly prepared semi solid White's basal medium containing 2 % sucrose and 0.42% agar.

8. After 25 days transfer the well-developed shoots to the shoot multiplication medium (1/2 strength MS liquid medium containing 2% sucrose, BA 0.5mg/l and Kn 0.5 mg/l supplemented with Coconut water 200 ml/l).
9. Place one shoot per flask on orbital shaker at 90 rpm.
10. Add fresh media for every 15 days interval.
11. After 30 days transfer the elongated shoots (5-7 cm) into 1/2 MS basal medium containing 2% sucrose, 0.42 % agar supplemented with IBA 0.25 mg/l for rooting.
12. Place the tubes in dark for 48 hr in a culture room
13. Select the rooted explants from the medium and transfer to a sterile beaker.
14. Wash the explants with sterile distilled water and dry with a blotting paper.
15. Transfer it to a plastic cup containing sterile Vermiculate: Soil (1:1) mixture.
16. Cover the cup with plastic paper and keep it in a growth chamber or culture room.
17. Maintain the cultures at 27-30 °C, 85-90 % RH, and 16/8 photoperiod.
18. Maintain for 2-3 weeks.
19. Remove the plastic bag.
20. Transfer the plants to fresh pot containing normal soil and keep it in a mist chamber.
21. Plants may take 4-5 weeks to acclimate.

A protocol for Micropropagation for mature tree explant

1. Collect fresh nodal explants from a healthy tree.
2. Cut the nodal explants into single shoot segments.
3. Treat with 5-10% (W/V) Teepol solution.
4. Shake vigorously and leave it under running water for one hour.
5. Sterilize the plants in 95% ethyl alcohol for 3 minutes followed by 0.1% (W/V) $HgCl_2$ under the laminar Airflow Chamber for 5-10 minutes and wash the explants in sterile distilled water 2-3 times.
6. Trim the nodal explants to 0.5 to 1 cm.
7. Inoculate the nodal segments in a freshly prepared White's basal

medium containing 2 % sucrose and 0.42% agar.

8. After 25 days remove the well developed shoots from the medium and transfer to 1/2 strength MS liquid medium containing 2% sucrose, BA 0.5mg/l and Kn 0.5 mg/l supplemented with Coconut water 200 ml/l for shoot multiplication.
9. Place one shoot per flask on an orbital shaker at 90 rpm.
10. After 30 days transfer the elongated shoots (5-7 cm) into a 1/2 MS basal medium containing 2% sucrose, 0.42 % agar supplemented with IBA 0.25 mg/l for rooting.
11. Place the tubes in dark for 48 hr in a culture room.
12. Select the rooted explants from the medium and transfer to a sterile beaker.
13. Wash the explants with sterile distilled water.
14. Transfer it to a plastic cup containing sterile Vermiculate: Soil (1:1) mixture.
15. Cover the cup with plastic paper and keep it in a growth chamber or culture room.
16. Maintain the cultures at 27-30 °C, 85-90 % RH, and 16/8 photoperiod.
17. Maintain for 2-3 weeks.
18. Add 1/10 strength MS macro elements stock at 3-5 day intervals.
19. Remove the plastic bag.
20. Transfer the plants to fresh pot containing normal soil and keep it in a mist chamber.
21. Plants may take 4-5 weeks to acclimate.

□□□

10

ECO-TECHNOLOGY

10.1 INTRODUCTION

Reclamation of mined dumps and mine spoils are the major concerns in protecting the environment (Barber 1984). Magnesite mine spoils, limestone mine spoils and quartz dumps are some of the problematic soils existing in Tamil Nadu. The Institute of Forest Research, Coimbatore, has developed packages for afforestation of these soils. The technology package includes physical and biological rehabilitation.

10.2 PHYSICAL REHABILITATION

This constitutes the major part of reclamation process of mine spoil.

- Analysis of physical, chemical and biological properties of mine spoil.
- Removing and storing the topsoil before mining for future afforestation.
- Leveling and shaping of the mine dump with convenient aspect and terraces, contours for planting.

10.3 BIOLOGICAL REHABILITATION

Rehabilitation of the minespoil can be made after studying the serial stages of various pioneer species, selection of suitable tree species and soil amendment techniques which include trenching around the plant, mulching with organic materials and cover crops, application of

biofertilizers and inorganic fertilizers (Wittwer, 1974 ; Power and Papendick, 1985).

10.3.1. Establishment of herbaceous vegetation

The locally available seeds and tillers, which will improve the site through their root system, may develop certain pioneer species like grasses and legumes and the resultant organic matter gradually changes the texture of soil for further succession.

10.3.2. Species selection

Species which are found locally and those that are capable of colonizing degraded areas should be preferred. The criteria for species selection may be listed as follows:

- Adopted to grow, spread and reproduce under severe condition.
- Provide quick green cover and soil binding.
- Leguminous species to fix atmospheric nitrogen and ameliorate the soil by addition of organic matter through plant litter.
- Fruit yielding trees to abode birds and other forms of wildlife and also encourage soil fauna.
- Plantation species with good economic, social and aesthetic value for local population.
- Fast growing indigenous and exotic species to accelerate plant succession.
- Control of erosion and stabilization of mine dump.
- Fire hardy, unbrowsable and stress tolerant.

Best performed species for Magnesite minespoil, Limestone minespoil and quartz sand dump

Magnesite minespoil	Limestone minespoil	Quartz sand dump
Acacia nilotica	*Eucalyptus tereticornis*	*Casuarina equisetifolia*
Casurina equisetifolia	*Acacia holosericea*	*Acacia auriculiformis*
C. junghniana	*A. auriculiformis*	*A.nilotica*
Ailanthus excelsa	*A. mellifera*	*Azadirachta indica*
Morinda tintoria	*A. nilotica*	
Ficus spp.	*Morinda tintoria*	
	Azadirachta indica	

Species suitable for stabilizing the slopes of minedumps		
Vinca rosea	*Tephrosia purpurea*	*Cassia auriculata*
Indigofera sumatrana	*Stylosanthes hamata*	*Agave sisalana*
Leucaena leucocephala	*Commiphora berryi*	*Cenchrus ciliaris*
Cymbopogan	*Jatropha curcas*	Local grasses etc.

Importance of tree species for the restoration of mine dump areas

Tree species	Importance
Acacia auriculiformis	Nitrogen - fixing tree, fuel
Acacia holosericea	Nitrogen - fixing tree, fuel
Acacia nilotica	Nitrogen - fixing tree, fuel
Ailanthus excelasa	Fast growing, drought tolerant
Alangium salvifolium	Fruit yielding
Annona squamosa	Fruit yielding
Azadirachta indica	Fruit yielding, multipurpose
Bambusa bamboo	Soil binder, drought tolerant
Casuarina spp.	Evergreen, fast growing and Nitrogen fixing tree, poli, fule
Emblica officinalis	Fruit yield, drought tolerant, attract birds, soil enriching, medicinal
Eucalyptus terticornis	Evergreen, fast growing, drought tolerant
Ficus benghalensis	Fruit yielding, attract birds, soil enriching
Ficus religiosa	Fruit yielding, attract birds, soil enriching
Holoptelia intergrifolia	Secondary timber, root suckers, drought tolerant
Morinda tinctoria	Fruit yielding, drought tolerant, secondary softwood, natural regeneration
Pithecollobium dulce	Fruit yielding, drought tolerant, attract birds & animals, natural regeneration
Santalum album	Fruit yielding, Sandal wood, attract bird & animals, natural regeneration
Tecoma stans	Attractive flowers, natural regeneration
Syzygium cumini	Fruit yielding, drought tolerant
Pterocarpus santalinus	Drought tolerant, Nitrogen fixing, timber
Wrightia tinctoria	Drought tolerant

10.4 MULCHING

Mulches such as agricultural refuse, sugarcane refuse, sewage sludge, straw, coir pith and jalsakthi can be applied around the seedlings in trenches, terraces and slopes which will alter the microclimate of the surface and help to conserve moisture during the establishment of plants.

10.5 APPLICATION OF BIOFERTILIZERS

Biofertilizers develop symbiotic association with plants which supply a protected niche to the microbes for growth and in return, the plants receive a continuous supply of atmospheric nitrogen and are capable of solubilising certain inorganic phosphates into utilizable forms through their enzyme action. Inoculating with suitable improved biofertilizer combination which is tolerant to heavy metal concentrations is one of the important techniques (Kumaravelu, 1993).

Biofertilizer dosage

Rhizobium	- 5 g/ plant
Azospirillum	- 5 g/plant
Phosphobacteria	- 5 g/plant
VAM	- 5 g/plant
Pisolithus tinctorius	- 5 g/plant

10.6 SPECIFICITY OF BIOFERTILIZERS FOR TREE SPECIES

Leguminous species	-	*Rhizobium*
Wide range of tree species	-	*Azospirillum,* VAM fungi and Phosphobacteria
Acacia & Eucalyptus spp.	-	*Pisolithus tinctorius*
Casuarina spp.	-	*Frankia*

Fertilizer application

Apply slow release fertilizers containing Nitrogen, Phosphorus and Potash during rainy season for establishing the vegetation in these areas and restore the fertility of the land.

The Forest Research Institute, Coimbatore has given technical consultancy in afforestation of floatation reject dump (Quartz sand) to ACC cement factory at Madukkarai, Tamil Nadu. This is a field level consultancy in which combination of species with suitable soil

amendments were recommended. This demonstration technology is being extended in the Quartz mine dumps by the ACC.

10.7 BIO-FERTILIZER APPLICATION FOR GROWTH ENHANCEMENT IN NURSERIES

The application of bio-fertilizers in nurseries is gaining importance in the recent years while raising quality planting stock. The bio-fertilizers not only boost the growth of seedlings but also ensure better survival and good health (Kumaravelu, 1993; Jaya balan 1993). The results of the experiment carried out at IFGTB are:

Delonix regia performed well when treated with *Phosphobacterium* and *Azospirillum* showing 200% and 58% increase in height respectively, over control.

Cassia siamea when treated with *Phosphobacterium* and *Azospirillum* showed 102% increase in height over control in both the cases and showed 21% increase when treated with *Rhizobium.*

In young teak plantation, application of *Azospirillum* and *Phosphobacterium* increased the height by 29% and girth by 9.5%.

The inoculation of *Frankia* and *Azospirillum* was found to be highly effective in *Casuarina equisetifolia.*

Ceiba pentandra responded well to *Phosphobacterium* and showed 58% increase in height over control.

Albizia lebbeek responded favorably to *Azospirillum* and *Phosphobacterium* inoculations showing 16-33% increase in height over control.

Triple inoculation of VAM, *Rhizobium* and *Phosphobacterium* in *Acacia nilotica* was found to be most promising in terms of growth.

In case of *Acacia nilotica* and *Albizia lebbeack*, *Glomus fasciculatum* species was found to be the best performing VAM fungus, while *Glomus intraradices* was the best for neem. Farmers, NGOs and State Forest Department, are adopting these packages.

□□□

11

FERTILIZERS

11.1 INTRODUCTION

Fertilizers provide plants with the nutrients necessary for healthy growth. Apart from the macronutrients, N, P, K, Ca, Mg and S there is a known suite of micronutrients (Fe, Mn, B, Cu, Cl, Zn and Mo) that play important roles in the plant's metabolism (Epstein, 1972).

When we use soil or compose-based media, the substrate might contain enough nutrients for good plant growth. However, it is advisable to analyze the substrate for available plant nutrients regularly. Although the optimal ranges are not known for most agro forestry tree species, figures for some general groups are available and can be used as guidelines. We can also monitor the plants themselves for symptoms of deficiency.

When using soil-less substrates, apart from compost, it becomes very important to fertilize seedlings. Most soil less media contain few or no nutrients and, with a few exceptions, their CEC is very low. Seedlings need nutrients from the growth substrate after the nutrients provided in the cotyledons become depleted. This is usually within the first couple of weeks after emergence; from then on, plants grown in a soil-less substrate need to be fertilized regularly and frequently (Mengel and Krikby 1987).

11.2 PLANT NUTRIENTS

All plants require nutrients to survive and grow. Plants take nutrients from the air, soil, and water, because we cannot see nutrients- they are colorless gases or are like dust dissolved in water or stuck into each piece of soil it is sometimes hard to understand how they work (Barber, 1984).

The quantity of nutrients available to the plants is affected by:

- Substrate quality
- Water quality
- Plant type.

Nutrients are taken up by the fine root hairs, not by the big roots. Even the very largest of trees have many small, fine root hairs to absorb the nutrients and water they need. The larger roots are used for supporting the trees and for storage of water and other plant food. The root hairs can also excrete liquids that affect the acidity of the soil (pH). With the pH changes, the amount of nutrients available may also change.

There are two sorts of nutrients; macronutrients, required in large quantities, and micronutrients, required in small quantities. The important three are nitrogen, phosphorus and potassium. Together they comprise over 75% of the mineral nutrients found in the plant (Epstain, 1972; Romheld and Marscher, 1991). All nutrients are abbreviated by one or two letters, their chemical symbols that are based on their Latin names. The symbols are the same in all languages.

Macronutrients	Micronutrients
Nitrogen (N)	Phosphorus (P)
Potassium (K)	Calcium (Ca)
Magnesium (Mg)	Sulphur (S)
Iron (Fe)	Manganese (Mn)
Zinc (Zn)	Copper (Cu)
Boron (B)	Chlorine (Cl)
	Molybdenum (Mo)

The only way to know if one nutrient is missing is to analyze the leaves, stems and roots in the laboratory and compare this to published values for that species. If values are not known, fertilizer trials might

show what is lacking. This would involve adding different types of nutrients and at different levels during the growing season. Soil analysis can show what is in the soil, but might not indicate what is available for the plants to use, and we might need a soil scientist to help interpret these results.

11.3 NUTRIENT BALANCE AND NUTRIENT DEFICIENCIES

Plants (like people) need a 'balanced diet'. They need all 13 nutrients to remain healthy. If one is missing, the plant will not grow well. Poor plant nutrition causes plants to grow slowly in the nursery and in the field, and to be more susceptible to diseases (Epstain, 1972).

Many people confuse the symptoms of nutrient deficiencies with those of too much or not enough shade or water. In fact, all three factors, shade, water and nutrients affect plant growth, and interact to produce healthy plants. A plant that grows in full light with abundant moisture and receives all the 13 nutrients will grow fast and have a dark green color in its leaves. A plant that grows slowly in the shade may also have dark green leaves, but when exposed gradually to the sun, the leaves may turn yellow. This does not mean that plants do not like full sun- it might indicate a nutrient deficiency, which did not show up in the shade because the plant did not have enough light to stimulate fast growth.

Together, water, shade and nutrients must be monitored and adjusted to produce quality seedlings.

It takes practices to learn the signs of identifying a missing nutrient or nutrients, but we can learn to do so, and some of the signs are common to many plants. A good nursery practice is to carefully, monitor the leaves of our plants for signs of nutrient deficiency, and correct them with a better substrate or with fertilizer.

11.4 INORGANIC FERTILIZERS

Inorganic fertilizers are mined from the soil, or produced during complicated chemical reactions. A good nursery practice is to read the fertilizer labels. This allows us to apply what the plants need without wasting nursery resources. Fertilizers contain only plant nutrients; they are not used to combat plant diseases or insects. Inorganic fertilizers do not improve the substrate physical properties, whereas organic material such as compost does. Inorganic fertilizers are also expensive and not

always available in the stores. Nursery managers should carefully consider the cost and benefit of buying these products.

Granular fertilizers are commonly given names like "17-17-17", or "10-30-10". What do the numbers mean? They represent the percentages of nitrogen (N), phosphorus (P), and potassium (K) in the fertilizer - 17% N, 17% P, and 17% K. in this case, 51% of the mixture is made up of N-P-K, and the rest is inactive material used to help spread the fertilizer evenly. Urea contains only N, and is labeled as 46-0-0. Urea is very strong and can easily burn the plants if too much is applied (Follett, 1981).

Granular fertilizers can be mixed into the substrate or into the irrigation water, or be applied to older plants on the soil surface. It is better to mix the fertilizer directly into the substrate before planting the seed because the roots can avoid or seek the fertilizer, as they need it. Use only small quantities such as 2 or 4 grams (1/2 teaspoon) per 1 kg of soil; it is better to add too little than too much. We need to experiment with different leaves. Plants should respond within two weeks.

When dissolving fertilizer in warm water, carefully note whether it is thoroughly dissolved. If not, it is probably the phosphorus that remains. It may be better to apply fertilizer (Barber, 1984).

In granular form if it does not dissolve thoroughly, apply liquid fertilizer to the soil, not to the leaves, which are easily burnt if fertilizer remains on them. Be extremely cautious when applying fertilizer to young plants.

Foliar fertilizers are used in order to get the nutrients to the plants quickly. They are specially formulated to apply directly on the leaves. Foliar fertilizers are absorbed by the leaves, not by the roots. When plants are acutely deficient in nutrients, foliar fertilizers, often help "green them up". Frequently, foliar fertilizer only contains the micronutrients, since it is assumed that the macronutrients are available in the substrate. However, some fertilizers such as 'Grogreen" contain both micronutrients and 20-30-10 of N-P-K. Often an adhering agent such as 'Da-plus' is used to help the fertilizer stay on the leaves so that it is not washed off in the rain. Because foliar fertilizers are expensive, and they may not encourage strong root growth, they should not be used as a long-term solution for plant nutrients (Power and Papendick, 1985).

11.4.1 Calculating fertilizer quantities

The following technique can be used for calculating the amount of fertilizer or any pesticide that is mixed with water. A typical foliar fertilizer recommends using one bag of fertilizer (1 kilo) per 200 liters of water. How much is needed then in one 15-liter backpack sprayer? We can simply approximate by dividing in half both amounts:

1 kilo (1000 grams) is for 200 liters

500 grams is for 100 liters

250 grams is for 50 liters

125 grams is for 25 liters

62.5 grams is for 12.5 liters

We would need a little more than 62 grams because the sprayer contains a bit more than 12 liters, or 75 grams, to fill the sprayer. If we divid the fertilizer in the bag into 10 equal parts each would weigh 100 grams. So in this case we would need a bit less than one-tenth of the bag.

Plants require 13 nutrients in different quantities to grow well. Common deficiencies symptoms help identify which nutrients are missing. Nutrient deficiencies should not be confused with the effects of too much or too little shade and water.

Good nursery practices

- Carefully monitor the leaves for signs of nutrient deficiencies, and correct them with compost (or) fertilizer.
- Understand fertilizer labels so that the right nutrients are applied.
- Thoroughly dissolve and dilute the granular fertilizer in warm water and apply it only to the soil, not the leaves.

Fertilizer can be applied in various forms as either organic or inorganic fertilizer.

11.5 ORGANIC FERTILIZERS

Compost from vegetative matter or animal manure due to its high nutrient content is also a valuable fertilizer and helps improve the physical and chemical properties of soil-based mixtures.

Organic fertilizer

Animal manure

Manure differs in its nutrient composition depending on the animal source and the season. This source will only have consistency if it is collected from reputable commercial farms where animals are fed a controlled and constant diet. In all cases where animal manure is used, include it in a composting programme. Leave manure to rot for 6-10 weeks to reduce the risk of 'burning' plants due to high nitrogen concentrations. This is particularly important for chicken or other bird manure in which nitrogen is very high. We can test whether manure is ready by using the method we employ for compost; put two handfuls of the moist material into a small plastic bag and leave it sealed for 24 hours in a dark place. If it heats up considerably and there is a strong smell of ammonia when, opening the bag, it is not ready to use yet. Apart from nutrients, manure adds a high amount of organic matter to a potting substrate and improves its physical conditions. Analytical monitoring of the nutrient composition of manure is essential for uniform plant production. Weeds and insects can easily be introduced into the nursery with manure unless it is properly composted. Manure can also be suspended in water and used for irrigation. This practice utilizes mainly the nitrogen component in manure.

Compost green matter

Like manure, compost properties vary with its components, the composting duration and the temperatures maintained during composting. If possible, do a chemical analysis of each batch before we use it. It takes considerable time and experience to produce compost of a uniform quality from batch to batch.

Animal waste These include hoof and horn meal, bone meal, fish meal and chicken feathers. There are fertilizers, which slowly release nutrients into the substrate. Hoof and horn meal and feather, are rich in nitrogen; bone and fishmeals rich in phosphorus. These materials also have a positive influence on the porosity of the substrate.

***Approximate nutrient contents of fresh manure of various farm animals**

	Nitrogen (%)	Phosphoric acid (%)	Potassium (%)
Cow	0.35	0.2	0.1-0.5
Goat/sheep	0.5-0.8	0.2-0.6	0.3-0.7
Pig	0.55	0.4-0.75	0.1-0.5
Chicken	1.7	1.6	0.6-1
Horse	0.3-0.6	0.3	0.5

Inorganic fertilizers

Macronutrients

Name (symbol)	Function	Deficiency symptoms (very general)
Nitrogen (N)	Important component of amino acids and proteins	Old leaves turn yellow, plant growth retarded. Be careful; too much nitrogen leads to susceptibility to diseases.
Phosphorus (P)	Provides energy (ATP). Helps in transport of assimilates during photo-synthesis. Important function in fruit ripening.	Small plants with erect growth habit; thin stems, slow growth. Leaves appear dirty grey-green, sometimes red.
Potassium (K)	Important in maintaining cell turgor, phloem trans-port, cell growth and cell wall development (K deficiency leads to susceptibility to pests	Older leaves show first chlorotic, later necrotic borders. Younger leaves remain small.

	because cell walls are weakened).	
Calcium (Ca)	Stabilizes cell membranes and cell walls, interacts with plant hormones. Ca is extremely immobile, can only be taken up through young, unlignified roots.	Deficiency is often only visible in retarded growth.
Magnesium (Mg)	Component of chlorophyll-photosynthesis is hindered when deficient. Binds ATP to enzymes, important for protein synthesis.	Old leaves chlorite from middle or between veins, rarely necrotic. Leaves orange-yellow, drop prematurely.
Sulphur (S)	Component of enteric oils, vitamin B, vitamin H, amino acids, and has important functions in protein synthesis. Tentative Soil Fertility Thresholds for Pines and Evcalyptus (inppm)	Similar to N-deficiency but symptoms show first on young leaves.

Tentative soil fertility thresholds for pines and eucalyptus (in ppm)

Element	Pines		Evcalyptus	
	Min	Max	Min	Max
P	25	200	25	200
K	8		10	
Ca	20		40	
Mg	3		3.5	
Mn	5	200	5	200
Cu	1	20	1	20
Zn	1.5	30	1.5	30
B	0.3	5	0.5	5

(*Source* : Romheld and Marscher, 1991)

11.6 GRANULAR INORGANIC FERTILIZER

Inorganic fertilizer is divided into single fertilizers, compound fertilizers and full fertilizers. They can be applied by broadcasting or by mixing with the irrigation water ('fertigation'). Fertilizers are commonly known by the contents of the main nutrients N, P and K. The numbers on the bags show the content of these components. For example 20-10-20 fertilizer contains 20% N, 10% P, usually in the form of P_2O_5[2], and 20% K, usually in the form of K_2O[3]. Urea, a single fertilizer contains only nitrogen labeled 46-0-0, indicating that it has 46% nitrogen, but neither phosphorus nor potassium. The remaining parts are made up of the non-N (P_2O_5, K_2O) part of the molecules and inert carrier materials.

When soil-less growth media are used, fertilizing with full fertilizers, which also include micronutrients, is necessary. Especially under tropical conditions and with irrigation, plants can grow actively throughout the year. This means that they need nutrients continuously and fertilizer needs to be applied at frequent intervals (weekly or fortnightly). Fertilizer should not be applied during germination, because it leads to increased bacterial and fungal infections. As seedlings develop, fertilizer schedules have to be adjusted. Some people use a mixture of fast- and slow-release fertilizers so that seedlings are planted into the field with a fertilizer reservoir. (Barber, 1984).

Types and examples of granular fertilizers

Single fertilizers	Contain only one nutrient; Urea (N) Super phosphate (P) Rock phosphate (P)
Compound fertilizers	Contain two nutrients; DAP (N, P) CAN (N, Ca)
Full fertilizers	Contain all three main nutrients; NPK 20-20-20 (N, P, K) NPK 17-17-10 (N, P, K) Also available with some or all necessary micronutrients; NPK 12-12-17-2 (N, P, K +mn) Bayfolan (N, P, K + micronutrients)

11.7 HOW TO CALCULATE THE RIGHT FERTILIZER CONCENTRATION

Usually, fertilizer requirements are given in ppm (parts per million), or mg/kg or L. if we use a 19-19-19 fertilizer, a 50-80 ppm solution is recommended for frequent use. Calculate the correct amount like this:

- In a 19% N (or P_2O_5, or K_2O) fertilizer, 100 g fertilizer Contains 19 g or 19000 mg N (or P_2O_5, or K_2O)
- A solution of 50 ppm is wanted (50 mg N in 1 L)
- 100g×50 mg/ 19000 mg=0.263 g or 263 mg.

For each liter of fertilizer solution, dissolve 263 mg of granular 19-19-19 fertilizer.

11.8 CONTROLLED-RELEASE FERTILIZER

Controlled- release fertilizers provide an attractive alternative to granular fertilizers. These are 'fertilizer cocktails' that slowly release nutrients to the substrate. The release depends on water availability or soil temperature. Controlled-release fertilizer is more expensive than the more common water-soluble fertilizer, but they have several advantages:

- The danger of over-fertilizing is reduced as the release of fertilizers occurs gradually,
- Fertilizing is necessary only occasionally, sometimes only once in a season,
- A balanced fertilizer mixture is provided at all times as the plants get what they need at different growth stages,
- Nutrients do not leach from the substrate so the plants receive all the nutrients applied.

Experimenting with controlled-release of fertilizers will help to determine the best application rates and times.

11.8.1 The principle of controlled-release of fertilizers

In some fertilizer companies using the osmocote technology, resins based on natural organic oils, such as soyabean (or) linseed oil, are used to coat fertilizers. Different thickness of resin coating is applied to the base fertilizer to achieve different release periods. Water enters the granule and dissolves the nutrients and they pass through the coating at a rate controlled by the soil temperature. As temperatures fluctuate the rate of nutrient release changes, matching plant demand as growth rates rise and fall in correlation with these changes. The resin coating remains intact

throughout the life of the product. When all nutrients are expended the coating dissolves. There are products for specific markers such as ornamentals, vegetables and nursery production. They last from 3-4 months to 16-18 months depending on the soil temperature. Estimated lifetime is based on an average temperature of 21°C; release rates change by about 12% for every 5°C. In a tropical environment with an average soil temperature of 28°C, a product labeled four months would last roughly three months. (Romheld and Marschar, 1991).

Examples of controlled-release of fertilizers

Fertilizer	Analysis (N-P-K)	Release mechanism	Length of time it lasts at 21°C	N source
Lesco	20-6-12	Temperature	4-6 Months	Sulphur coated urea and amononium nitrate.
MagAmp	7-40-6 + 12Mg	Moisture	4-12 months	Magnesium ammonium phosphate.
Osmocote	18-6-12 14-14-14 13-13-13 19-6-12 17-7-12	Temperature, Coating, Thickness; no changes with media moisture	8-9 months 3-4 months 8-9 months 3-4 months 12-14 months	Ammonium Nitrate and Ammonium Phosphate.
Sulphur Coated urea	36-0-0 + 17S	Temperature, media moisture, coating thickness	Up to 6 months, approx.1% per day	Sulphur coated urea
Urea form	38-0-0	Increases with temperature, maximum at pH 6.1 and 50% water saturation; bacterial action	60% in 6 months	Urea-formaldehyde

Most of these products are available on the international market, sometimes under a different name. For example, g" 20-10-20 is a product of phostogen that acts using the osmocote technology.

(*Source*: Follett et al., 1981)

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□□□

RECENT ADVANCES IN BAMBOO RESEARCH

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FOREWORD

Bamboo as a forest produce has many uses. They are particularly important for the people of the East, where, they are found in greatest abundance and variety. No doubt, this amazing tree-grass has played a - significant role in the life and activities of man and perhaps, no growing thing on the earth has so many and varied uses as the bamboo.

However, we know very little about several-aspects of this giant arborescent grass (bamboo) and these are receiving a high priority in the research activities of bamboo specialists. Lack of adequate information on the local bamboo resources and their optimum utilisation potential has been a drawback in its promotion. To address this problem, Dr. P. Shanmughavel of Bharathiar University, Coimbatore, Mr. R.S. Peddappaiah of the Institute of Wood Science and Technology, Bangalore and Prof. Walter Liese of Leuschnerstr, Germany have collected the results of the recent investigation of this fascinating plant and the compendium of papers contained in this book will definitely add to the existing information and further lead all those, who are interested in the different aspects of this wonderful grass. The work of the authors, in bringing such a publication, deserves appreciation.

Bangalore
12.02.2002

Dr. K. Kesava Reddy
Principal Chief Conservator of Forests (Retd.)
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PREFACE

Bamboos are one of the world's greatest natural and renewable resources. It is integral to the culture of South and South-East Asia. Every country has its own indigenous bamboo flora. Over 75 genera and 1250 species are reported to occur in the globe. Of late, the demand for this material has increased for beyond the availability, causing serious problems of over-exploitation and depletion of resources. A sustained availability can be ensured only by elaborate bamboo cultivation.

Research work has been geared-up in the field of plantation bamboo. Its biology, embryology, cytology, ecology, silviculture and utilization are known which are receiving a high priority in the research activities of bamboo specialists. This book with 32 research and review articles provides in-depth information on these aspects. The contributors of this book are all eminent authors from different countries, actively engaged in the fields of their research. We are grateful to them for their valuable efforts in the preparation of this book. We are sure, this book should prove invaluable to those who are interested in the different aspects of this wonderful grass.

Dr. P. Shanmughavel
Mr. S. Peddappaiah
Prof. Dr. Walter Liese

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Date :

FORWARD

Forests are valuable in our lives, crucial to our nation's economy and integral to our long term health of the environment. However, it is deplorable that this natural resource is being deliberately plundered invariably for greed. To meet these challenges, new approaches and new resources should be augmented for initiation, development and redirection of basic and applied research. Knowledge gained from an improved system of forestry research will enable society to choose wise-use and thus to secure environmental, economic and spiritual benefits of forests. The demand for scientific based information and expert opinion on environmental issues and human-forest interactions are on the increase. Researchers and foresters are responsible for keeping the public informed about the status of forestry research and global environmental issues. To address this problem, Dr. P. Shanmughavel and Rev. Fr. Dr. S. Ignacimuthu, S.J. have collected the results of recent investigations of forestry research and the compendium of papers contained in this volume will definitely add to the already existing information and may lead to further research for those who are interested in the different aspects of forestry. The work of authors in bringing such a publication is highly laudable.

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STUDIES ON THE GROWTH OF *BAMBUSA BAMBOS* AT KALLIPATTY, TAMIL NADU

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Abstract

A brief account on the growth of *Bambusa bambos* in an irrigated plantation at Kallipatty, Tamil Nadu is presented.

Introduction

Bamboo forests occupy large tracts of land in India. The main bamboo species occurring in Tamil Nadu are *Bambusa bambos* and *Dendrocalamus strictus*. Bamboo is used in nearly every aspect of daily life. The growth pattern and productivity of different bamboo species is studied by several workers (Deogun, 1936; Kadambi, 1949; Sen Gupta, 1952; Krishnasamy, 1952; Seth, 1954; Huberman, 1959; Banik, 1988 and Razak Othman, 1992). With the increase in various developmental activities the demand for bamboo has risen tremendously. One way to increase the production is to raise plantations of bamboos. An experimental trial of *Bambusa bambos* was conducted at Kallipatty near Sathyamangalam, Tamil Nadu.

Materials and Methods

Study area

The study area is located at Kallipatty between 11° 28' and 12° latitude and 76° 59' and 77° 47' longitude. Its altitude is 540m MSL. This area has red soil. Soil pH is between 7.4 and 7.8. The maximum soil nitrogen, phosphorus and potassium were determined to be 176 kg/ha 33 kg/ha and 225 kg/ha respectively. The mean temperature is 31°C. Mean annual rainfall is about 600 mm.

Preparation of nursery and planting

Nursery area of 10 m x 5 m were prepared in the field and filled with a mixture of soil and sand (3:1). The seedlings, when about 7 cm in height, were pricked out from the polythene bags. About 25-30 seedlings were planted in 1 m^2 of raised nursery bed. Watering was done 2-3 times a day, and care was taken to avoid over saturation. Nursery beds were provided with a thatch to protect the seedlings from direct sunlight.

Transplanting

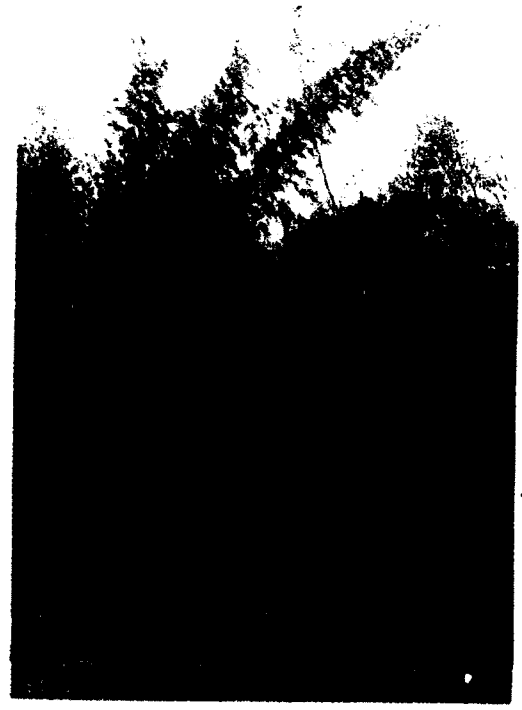
The seedlings in the nurseries were uprooted carefully and transplanted to the field during August (after about 9 months). The seedlings were planted with 6 m x 6 m spacing in 3 ha area with 250 seedlings/ha. The transplanted seedlings were watered two hours regularly in the morning and evening. Weeding was done as and when required. After one year, the plantation was adequately irrigated at 15 days interval. Care

was taken to avoid water logging. Protection against damage by rodents, grazing and browsing animals was provided.

Results and discussion

Production of culms

All the transplanted seedlings produced rhizomes. The culm buds emerge with the onset of early rains and grow rapidly. They reach full height within 90 days. An unusual rain during winter months may induce the emergence of new culms but they do not grow successfully, like those produced in rainy season. The culms are very tender during the growing period. It has been observed that the daily height growth of culm is approximately 33 cm. The internodes are wrapped with sheaths. In the first month, the culms lose their sheath and develop side shoot buds. These shoot buds start to elongate during the second month. The maximum length of side shoots is up to 150 cm. In the third month, side shoots develop leaves. Then the culms continue to change in density. After this they start changing colour. The new culms formed along the outside edge of the clump later on tend to grow inwards and get entangled among the older culms.



A view of bamboo forests at Kallipatty

Annual recruitment of culms

The productivity of bamboo is assessed by the number of new culms produced annually. At a given site the production of new

Table 1. Growth data of *Bambusa bambos*

Age of the plantation (yrs)	Number of culms/clumps	Average height (m)	Average girth (DBH) (cm)	Number of nodes/per culm
1	5	1.4	2.3	7
2	9	3.2	3.3	16
3	14	9.6	4.3	37
4	15	21.8	4.8	86
5	11	27.2	6.3	114
6	17	28.9	8.3	127

culms was mostly depend on the culms of the previous year, the degree of congestion and the clump age. It was observed that culm emergence took place in 1988, the following year of planting. Seedlings of *Bambusa bambos* produced only 5 culms per clump in the first year after planting. The average number of culms gradually increased in the subsequent years to 9, 14, 15, 11 and 17 per clump (Table 1). It was noticed that culms emerged in the first year were short (1.4 m) in length and smaller (2.3 cm) in diameter at breast height. Culms produced in subsequent years were distinctly taller and larger in diameter.

Conclusion

The *Bambusa bambos* plantation raised at Kallipatty has attained great success mainly due to irrigation and protection from biotic interference. The result from the growth of *Bambusa bambos* plantation can be used as guidelines for taking up large scale plantations on suitable sites.

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Short Communications

Economics of *Bambusa arundinacea* Plantations

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Bamboo is used in nearly every aspect of daily life. Bamboo is a vernacular term for members of sub-family Bambusoideae of family Poaceae—the grasses. Of about 1250 species of bamboos belonging to 75 genera nearly 136 species occur in India. They range from the size of grasses to giants of 40 m height and 30 cm in diameter. Bamboos are most abundant in seasonal monsoon forest and prefer disturbed habitats in which they often become weedy. India is one of the leading countries of the world, second only to China in bamboo production with 3230000 tonnes per year [2]. The main bamboos in Tamil Nadu are *Bambusa arundinacea*, *Dendrocalamus strictus*, and *Ochlandra travancorica* is found growing as a pure crop in Tinnevelly North division. It also occurs in small patches in Coimbatore and Madurai divisions. Main bamboo areas in the State are found in the districts of North Arcot, Trichirapally, Nilgiris [5]. Bamboo is mainly used by the household sector for house construction and in making farm implements, mats, fences, baskets and other handicrafts and as supporting poles for agricultural crops. Although reports on the status of research, inventory production and utilization aspects of Indian bamboos are recorded in literature [1,3,4,6,7,8,9]. These are inadequate. The research on production and marketing will indicate the appropriate means for improving the capabilities of the rural people in producing bamboo based products. With these ideas the present work has been undertaken to study the economics of *Bambusa arundinacea* plantations.

Study Area : The study area is located at Kallipathy, 28 km from Sathyamangalam lies between 11°28' to 12° lat and 76°50' to 77°47' E long. It is approximately 540 m above mean sea level. The climate of the area is monsoon. High velocity winds blow during South-West monsoon. Soil of this area is red soils. Soil pH was between 7.4-7.8. The elective conductivity of the soil was 0.1. The maximum soil nitrogen, phosphorus and potassium was 176 kg/ha and 225 kg/ha respectively. The mean temperature was 32°C. Maximum rain fall 316 mm. The mean relative humidity was 82 per cent.

Bambusa arundinacea Plantations : The seedlings of *Bambusa arundinacea* were planted with 6 m × 6 m spacing on three hectares during August 1987, at Kalli-

pathy located 28 km from Sathyamangalam, Tamil Nadu. Almost every seedlings produced culm in 1988, the next year of plantation. Since then the clumps were treated as 1 year old and recording of different growth measurements have been continued for five years. All the seedlings produced only 2-5 full grown culms per clump in the first year after plantation. The number of culms gradually increased in the subsequent years and became more or less maximum in the 6th year of clump age. The economics of bamboo plantations was studied at the end of the 6th year. Table 1 presents the extent of production of *Bambusa arundinacea* plantations (different age groups).

Table 1. Production of *Bambusa arundinacea* plantations.

Item	Years					
	1988	1989	1990	1991	1992	1993
Nos. of clumps/ha	250	250	250	250	250	250
Nos. of culms/culmp (average)	5	9	14	15	11	17
Culm height (average) (m)	1.4	3.2	9.6	21.8	27.2	28.9
DBH (average) (cm)	2.3	3.3	4.3	4.8	6.3	8.3
Nodes/culm	7	16	37	86	114	127

Yield and Financial Results and Discussion : Yields of bamboos varies widely in different climatic zones. It also depends on the density of the crop. Therefore, its financial viability is dependent on climatic silvicultural practices adopted and market conditions. It is necessary to quantify some of the intangible benefits of bamboo forests in economic analysis [5].

The cost for maintenance and expenditure incurred on extraction of bamboo for six year old *Bambusa arundinacea* plantations were given in Table 2. The cost of raising the entire plantation and maintaining it until 6 year maturity was Rs. 44180. The expenditure incurred on extraction of the bamboos was Rs. 108125. The local revenue realised by the sale of extracted bamboos is Rs. 231500.

On the whole 10,750 culms (including 4, 5, 6 age groups) were obtained from 250 clumps per hectare. Along with the exploitation, a cleaning of the clump was also done to facilitate the development of new culms. The thorns obtained during extraction were also sold for what they worth. The main principal followed were that a minimum of six mature culms would be left in each clump and all tender bomboos less than a year old would be left without cutting. In actual practice more culms were left in the clumps to be on the safe side.

From the financial results obtained

Table 2. Cost for maintenance and expenditure incurred on extraction of bamboo.

Years	Cost of raising the plantation and maintenance (Rs.)	Expenditure incurred on extraction of bamboo (Rs.)	Total expenditure (Rs.)	Total revenue obtained (Rs.)
(1) 1988	11,400	—	11,400	—
(2) 1989	6,750	—	6,750	—
(3) 1990	5,145	—	5,145	—
(4) 1991	6,415	30,000	36,415	56,250
(5) 1992	6,320	28,125	34,445	60,500
(6) 1993	8,150	50,000	58,150	1114,750
Total	44,180	108,125	152,305	231,500

Surplus amount Rs. 79,195.

it could be seen that a net surplus of Rs. 79195 has been obtained from one hectare of plantation after five years. From the general observations made in the plantation of fresh culm production, we can expect more yield in the following felling cycle and prices of bamboos remaining the same (likely to increase) the financial return also can be expected to be as good.

The details of simple economic analysis of cost and benefit of *Bambusa arundinacea* plantations were presented in Table 3. It can be concluded that the establishment of *Bambusa arundi-*

Table 3. Cost benefit analysis for six year old *Bambusa arundinacea* plantation at Kallipathy.

Year	Cost	Benefit	Present value under different discount rate					
			12%		14%		16%	
	(Rs.)	(Rs.)	Cost (Rs.)	Benefit (Rs.)	Cost (Rs.)	Benefit (Rs.)	Cost (Rs.)	Benefit (Rs.)
1	11400	—	10032	—	9804	—	9596	—
2	6750	—	5940	—	5805	—	5670	—
3	5145	—	4527	—	4340	—	4321	—
4	36415	56250	32047	49500	31319	48375	30591	47250
5	34445	60500	30311	53240	29622	52030	28933	50820
6	58150	1147750	51172	100980	50009	98685	48846	96390
Total	1,52,305	1,26,450	1,34,029	2,03,720	1,30,899	1,99,090	1,27,957	1,94,460

Discount rates : 12% B/C ratio 1:51; 14% B/C ratio 1:52; and 16% B/C ratio 1:52.

nacea plantation is not profitable at the end of three years. However after this period, it is noticed that cost benefit ratio (B/C) exceed 1.0, showing very good financial results.

Economics of bamboo plantations in Uttar Pradesh was worked out by Chaturvedi (1986). According to him, the benefit cost (B/C) ratio 1:7 at 14.5 per cent rate of discount. In another study [5] has tested the economic parameters on costs and benefits data of one hectare bamboo plantation in Madhaya Pradesh, and found benefit cost ratio (B/C) as 1:85 at 14 per cent discount rate. In this study, the cost benefit ratio (B/C) as 1.51 at 12 per cent discount rate and 1:52 at 14 and 16 per cent discount rate.

Conclusion : The uses of bamboos in and around Sathyanangalam is broad and the variety of applications numerous. The result from the studies on culm production pattern and marketing of bamboo product can be used as a guidelines for the improvement of bamboo resource utilization as well as for improvement of income distribution.

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A Preliminary Report on Economics of *Bambusa arundinacea* Plantations

P Shanmughavel

ABSTRACT

A study on the production of bamboo shoots and a preliminary economic analysis for bamboo plantation is presented.

Key words : Economics, bamboo, yield, seedling humidity, maturity, plantation

INTRODUCTION

Bamboo is used in nearly every aspect of daily life. Bamboo is a vernacular term for members of sub-family Bambusoideae of family Poaceae, the grasses. Of about 1,250 species of bamboos belonging to 75 genera nearly 136 species occur in India. They range from the size of grasses to giants 40m. height and 30 cm. in diameter. Bamboos are most abundant in seasonal monsoon forest and prefer disturbed habitats in which they often become weedy.

India is one of the leading countries of the World, second only to China in bamboo production with 32,30,(XX) t yr^{-1} (Pathak 1989). The main bamboos in Tamil Nadu are *Bambusa arundinacea*, *Dendrocalamus strictus*, and *Ochlandra travancorica* found growing as a pure crop in Tinnevelly North division. It also occurs in small patches in Coimbatore and Madurai divisions. Main bamboo areas in the state are found in the districts of North Arcot, Trichirapally, and Nilgiri (Tewari 1991). Bamboo is mainly used by the household sector for house construction and in making farm implements, mats, fences, baskets and other handicrafts and as supporting poles for agricultural crops. Although reports on the status of research, inventory, production and utilization aspects of Indian bamboos are recorded in literature (Tomar 1974, Varmah and Bahadur 1980, Gaur 1985, Varmah and Pant 1981, Sharma N 1987, Thomas et al. 1987 and Kochhar et al. 1988), these are inadequate. The research on production and marketing will indicate the appropriate means for improving the capabilities of the rural people in producing bamboo based products. With these ideas, the present work has been undertaken to study the economics of *Bambusa arundinacea* plantations.

STUDY AREA

The study area is located at Kallipathy, 28 km from Sathyamangalam (11° 28' to 12° N lat, 76° 50' to 77° 47' E long, altitude 540m). The climate of the area is mon-

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soonal. High velocity wind blow during South-West monsoon. Red soil are present. Soil pH was between 7.4 to 7.8. The electric conductivity of the soil was 0.1 M.s. cm^{-1}. The maximum soil nitrogen, phosphorus and potassium were 176 $kg^{-1}ha$, 33 $kg^{-1}ha$. and 225 $kg^{-1}ha$. respectively. The mean temperature was 32°C. Mean rainfall was 316 mm. The mean relative humidity was 82 per cent.

Bambusa arundinacea plantations

The seedlings of *Bambusa arundinacea* were planted with 6m x 6m spacing in 3 ha area with 250 seedlings ha^{-1} at Kallipathy located 28 km from Sathyamangalam, Tamil Nadu. Almost every seedling produced culm in 1988, the next year of plantation. Since, then the clumps were treated as 1 year old and recording of different growth measurements were continued for five years. All the seedlings produced only 2 to 5 full grown culms per clump in the first year after plantation. The number of culms gradually increased in the subsequent years and became more or less profuse in the 5th year of clump age. The economics of bamboo plantations was studied at the end of the 5th year. Table 1 presents the extent of production of *Bambusa arundinacea* plantations.

Table : 1 *Production of* Bambusa arundinacea *plantations*

Age of the plantation (Yrs)	Number of culms per clumps	Average height (m)	Average girth (cm)	Number of nodes per culm
1.	5	1.5	3.0	10
2.	20	4.0	7.0	20
3.	35	9.0	10.0	38
4.	52	20.0	14.0	80
5.	63	28.0	16.5	108

Table 2 : *Cost benefit analysis for 5 year old* Bambusa arundinacea *plantation*

	INR
Total number of culms (all ages)	15,750
Matured culms (eligible for exploitation)	7,000
Price/culm (Average)	30
Total value or revenue ha^{-1}.	2,10,000
Expenditure for maintenance etc.,	1,01,000
Profit	1,09,000
Net Profit ha^{-1}	21,800

YIELD AND FINANCIAL RESULTS

Table 2 presents the details of simple economic analysis of cost and benefit of these plantations. The cost of raising entire plantation and maintaining it until maturity was Rs. 24,000 ha^{-1}. The expenditure incurred on extraction of the bamboos was Rs. 77,000 ha^{-1}. The total revenue realised by the sale of the extracted bamboos is Rs. 2,10,000 ha^{-1}.

On the whole, 15,750 culms (including all age groups) were obtained from 250 $culm^{-1}ha$. of which 7,000 culms ha^{-1} were well matured and eligible for exploitation. Along with the exploitation, a cleaning of the clump was also done to facilitate the development of new culms. The thorns obtained during extraction were also sold for what they were worth. The main principle followed was that a minimum of 6 mature culms would be left in each clump and all tender bamboos less than a year old would be left without cutting. In actual practice more culms were left in the clumps to be on the safe side.

From the financial results obtained, it could be seen that a net surplus of Rs. 1,09,000 was obtained from one ha of the plantation after five years. So, the profitability of bamboo cultivation would be of the order of Rs. 21,800 ha^{-1} yr^{-1} while it may be favourable in comparison to most rainfed crops, and cannot ignore the 5 years waiting period of bamboo cultivation vis-a-vis ordinary field crops. (Discounting analysis has to be done for reckoning with the waiting period). From the general observations made in the plantation of fresh culm production, we can expect more yield in the second felling cycle and prices of bamboos remaining the same (likely to increase), the financial return also can be expected to be as good.

CONCLUSION

The result from the studies on culm production and marketing of bamboo product can be used as a guideline for the improvement of bamboo resource utilization as well as for improvement of income distribution.

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PRODUCTION AND UTILIZATION OF *BAMBUSA BAMBOS* AT KALLIPATTY, TAMIL NADU

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Abstract

This paper reports the production and utilization of *Bambusa bambos* Druce at Kallipatty, Tamil Nadu. The annual productivity of *Bambusa bambos* in an age series is presented, utilization of bamboos in and around Kallipatty is discussed.

Introduction

Bamboo is one of the most wonderful and valuable gift of nature to man. Bamboos are used in nearly every aspect of daily life. With the increase in developmental activities the demand for bamboo has risen tremendously. For many centuries bamboos have played an essential role in the daily life of the people in tropical countries (Sharma 1987, Zhou 1983). Although reports on the status of research, inventory, production and utilization aspects of Indian bamboos are recorded in literature (Tomer, 1974; Varmah & Bahadur, 1980; Gaur, 1985; Varmah & Pant, 1981; Sharma, 1987; Thomas *et al.*, 1987 and Kochhar *et al.*, 1988); no literature is available regarding the production and utilization aspects of this at Kallipatty. Hence an attempt has been made to study the production and utilization of *Bambusa bambos* at Kallipatty, Tamil Nadu and is presented here.

Study Area

The study area is located at Kallipatty, 28 km from Sathyamangalam lies between 11° 28' to 12° N lat. and 76° 59' to 77° 47' E long. It is approximately 540 m above mean sea level. The climate of the area is monsoonic. This area has red soil. Soil pH is between 7.4 and 7.8. The maximum soil nitrogen, phosphorus, and potassium are 176, 33 and 225 kg/ha respectively. The mean temperature is 32°C. Mean annual rainfall is about 320 mm.

Bambusa bambos Plantations

The seedlings of *Bambusa bambos* were planted with 6 m x 6 m spacing in 3 ha area with 250 seedlings/ha during August 1987. The transplanted seedlings were watered regularly in the morning and evening. Weeding was done as and when required. After one year, the plantation was adequately irrigated with 10 days interval. Care was taken to avoid water-logging. Protection against damage by rodents, grazing and browsing animals were provided.

Productivity of *Bambusa bambos*

The productivity of bamboo is assessed by the number of new culms produced annually. At a given site the production of new culms was mostly dependent on the culms of the previous year, the degree of congestion and the clump age. It was observed that culm emergence took place in 1988, the following year of planting. Since then the culms were treated as 1 year old and recording of different measurements continued. Seedlings of *Bambusa bambos* produced only 5 full grown culms per clump

Table-1: Production of *Bambusa bambos* plantation

S.No.	Item	1988	1989	1990	1991	1992	1993
1.	No. of clumps/ha	250	250	250	250	250	250
2.	No. of culms/clumps (average)	5	9	14	15	11	17
3.	Culm height (average in cm)	1.4	3.2	9.6	21.8	27.2	28.9
4.	DBH (average in cm)	2.3	3.3	4.3	4.8	6.3	8.3
5.	Nodes/culm	7	16	37	86	114	127
6.	Total culms/ha	1250	2250	3500	3750	2750	4250

in the first year of planting. The number of full grown culms gradually increased in the subsequent years to 9, 14, 15, 11 and 17 per clump (Table-1). It was noticed that culms emerged in the first year were short (1.4 m) in length and smaller (2.3 cm) in diameter at breast height. Culms produced in subsequent years were distinctly taller and bigger in diameter.

Utilization

The strength of bamboo culms, their straightness and lightness, combined with hardness, range in sizes, hollowness, long fibre, and easy working qualities, made them suitable for variety of purposes. The utilization of bamboo in and around Kallipatty are as under:

1. The *Bambusa bambos* used for modern products such as baskets, kitchen containers, wall plaques, table mats and lamp shades.
2. Weaving of baskets for packing and transport of flowers.
3. The use of bamboo in housing and construction is limited. The bamboo is used in housing as scaffolding supports and props in the building sector.
4. The leaves are utilized as cattle-fodder.
5. Many articles of common domestic use like, toys, hats, wall plates, wall hangers, tray, etc., are made from bamboo.
6. For sericultural practices, bamboo padels are weaved and used, by the nearby farmers.
7. Bamboo wastes are used as fuel in this area.
8. Sri Ramakrishna mills at Ariappampalayam 30 km from Kallipatty purchase 90 cm long bamboo stripes for their uses from this farm.

Bamboo from Kallipatty farm is not sold for paper and pulp making to Sri Sheshashayee Papers Limited and South India Viscose Ltd. due to the non-availability of demanded prices.

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BAMBUSA BAMBOS — AN IDEAL SPECIES FOR COMMERCIAL PLANTATION

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SUMMARY

Over-exploitation and shrinkage of their natural habitat is depleting the bamboo resource at an alarming rate. Sustained availability can be ensured only by plantations. This paper describes the results from a trial plantation of *Bambusa bambos*. This proved to be an ideal species for large-scale plantations. Productivity, pulp characteristics and economic aspects are discussed.

INTRODUCTION

Bamboos are giant, woody, tree-like grasses with a long history as an exceptionally versatile and widely used resource. Over 75 genera and 1,250 species have been identified (Soderstorm and Ellis, 1987). Bamboo is a cultural feature of South and Southeast Asia. No country in the region is without an indigenous bamboo flora. Its plethora of essential uses has led to the use of terms such as the "poor man's timber", the "Cradle to Coffin plant", "green-gold", "bamboo friend of the people" and it still provides the material needed for existence. Yet over-exploitation associated with growing human populations, destruction of tropical forests and new demands on the resources for industrial uses, especially by the pulp and paper industry, has resulted in wide scale decimation of bamboo stocks. Compared with the vast forests of bamboo found in South and Southeast Asia at the beginning of this century, we are left with the current situation of acute scarcity. Efforts are therefore underway to research into cultural and agronomic techniques which will boost bamboo production so that raw material in sufficient quantity can be made available to farmers, rural households and large industries.

Research has increased rapidly in recent years. The growth pattern and productivity of different bamboo species has been studied by several workers. (Deogun, 1936; Kadambi, 1949; Sen Gupta, 1952; Krishnasamy, 1952; Seth, 1954; Huberman, 1959; Banik, 1988; Othman, 1992; and Shanmughavel and Francis, 1993a). Activities, were strengthened by the creation of a IUFRO Project group on Bamboo in 1976. This was followed by an IDRC IUFRO Workshop in Singapore 1980 (IDRC, 1980) a subsequent conference at the IUFRO congress in Kyoto 1981. (Higuchi, 1981) and an international workshop in Hangzhosuw 1985. Organised by the Chinese Academy of Forestry and IDRC in co-operation with IUFRO (IDRC, 1986). A third international Bamboo workshop was held in

Cochin 1988, organised by KFRI and IDRC, and the fourth was in Chiengmai, Thailand in 1991. Preparations and planning are now well under way for the next international workshop in Bali, Indonesia in June 1995. These efforts are already bearing fruit.

The present crisis in sustained availability can be ensured only by raising bamboo plantations. In view of this, an experimental trial of *Bambusa bambos* was conducted at Kallipatty, near Sathyamangalam, Tamil Nadu, India. A survey of literature reveals that work on growth and organic productivity, pulp and paper characteristic and nutrient distribution and cycling of *Bambusa bambos* is very meagre, with practically nothing on plantations. Hence a thorough study was carried out. The study revealed that *Bambusa bambos* is an ideal species for commercial plantations. The results obtained are reported in this paper.

STUDY AREA

The study area is located at Kallipatty between 11°28′ and 12° latitude and 76°59′ and 77°47′ longitude. Its altitude is 540 masl. This area has red soil, with pH between 7.4 and 7.8. Soil nitrogen, phosphorus and potassium were 3800 kg/ha, 360 kg/ha, 3600 kg/ha respectively. The mean temperature is 31°C. Mean rainfall is 600 mm..

NURSERY MANAGEMENT PRACTICES

A nursery area of 10 m×5 m was prepared in the field and filled with a mixture of soil and sand (3:1). The seedlings were pricked out from the polythene bags when about 7 cm in height. About 25–30 seedlings were planted in 1 m^2 of raised nursery bed. Watering was done 2–3 times a day, and care taken to avoid over-saturation. Nursery beds were provided with a thatch to protect the seedlings from direct sunlight.

TRANSPLANTING

The seedlings in the nursery were uprooted carefully and transplanted to the field during August (after about 9 months). The seedlings were planted with 6 m × 6 m spacing in 3 ha. area with 250 seedlings/ha. The transplanted seedlings were watered two hours regularly in the morning and evening. Weeding was done as and when required. After one year, the plantation was adequately irrigated at 15 day intervals. Care was taken to avoid water logging. The plantation was protected against damage by rodents, grazing and browsing animals.

GROWTH AND PRODUCTION OF CULMS

All the transplanted seedlings produced rhizomes. The culm buds emerge with the onset of early rains and grow rapidly. They reach full height within 90 days. An unusual rain during the winter months may induce emergence of new culms but they do not grow successfully, like those produced in rainy season. The culms are very tender during the growing period. It has been observed that the daily height growth of a culm is approximately 33 cm. The internodes are wrapped with sheaths. In the first month, the culms lose their sheath and develop side shoot buds. These start to elongate during the second month. The maximum length of side shoot is up to 150 cm. In the third month side shoots develop leaves. Then the culms continue to change in density. After this they start changing colour. The new culms formed along the outside edge of the clump later on tend to grow inwards and get entangled among the older culms.

ANNUAL RECRUITMENT OF CULMS

The productivity of bamboo is assessed by the number of new culms produced annually. At a given site the production of new culms mostly depends on the culms of the previous year, the degree of congestion and the clump age. In the trial plantation, culm emergence took place in 1988, the year following planting. Seedlings of *Bambusa bambos* produced only 5 culms per clump in the first year after planting. The average number of culms gradually increased in the subsequent years to 8, 12, 14, 16 and 17 per clump. Culms emerging in the first year were short (1.4 m) in length and small in diameter (2.3 cm dbh). Culms produced in subsequent years were distinctly taller and thicker.

PRODUCTIVITY

The mean grand total per culm tripled in each of years 1 and 2. Increments then declined, though from the end of Year 2 to the end of Year 6, biomass rose from 17.5 kg to 70.1 kg.

The total standing biomass (mg ha^{-1}) was calculated using data on the density of the bamboos of different ages (Table 1). Dry matter production increased progressively to reach 286.6 Mg ha^{-1} by the sixth year. In comparison with earlier results (Toky and Ramakrishnan, 1983; Rao and Ramakrishnan, 1988; Othman, 1993) it was observed that productivity was higher in the present study.

TABLE 1

Productivity of *Bambusa bambos* (Mg ha^{-1}) Plantation

Age (year)	Average height (m)	Average diameter (cm)	Basal Area (cm)	Total Number of culms	Number of nodes	Biomass mg ha^{-1}			Total above ground biomass	Rhizome	Grand total biomass
						Leaf	Branches	Culm			
1	1.4	2.3	3.1	1250	7	0.166	0.493	0.698	1.356	0.938	2.294
2	3.2	3.3	4.0	2250	16	0.668	1.897	6.795	9.360	3.150	12.510
3	9.6	4.3	5.0	3000	37	1.122	17.115	29.250	47.487	4.980	52.467
4	21.8	4.8	6.1	3500	86	1.862	27.160	92.750	121.772	6.055	127.827
5	27.2	6.3	8.3	4000	98	3.544	33.940	187.224	224.708	9.600	234.308
6	28.5	8.3	10.1	4250	103	4.021	39.886	242.730	286.637	11.220	297.857

PROXIMATE CHEMICAL ANALYSIS

The chemical composition of *Bambusa bambos* did not vary greatly from year 1 to year 6, but there was a rise in the holocellulose, lignin and ash content (Table 2).

TABLE 2

Proximate Chemical Analysis

Results	Years					
	1	2	3	4	5	6
Holocellulose (%)	60.1	61.2	62.5	63.3	64.5	65.6
Lignin (%)	28.0	28.5	29.0	30.5	31.5	32.0
Pentosans (%)	10.10	10.32	19.53	19.62	20.0	20.2
Cold water solubility (%)	4.0	4.0	4.2	4.3	4.5	4.5
Hot water solubility (%)	4.47	4.60	4.90	5.10	5.80	5.95
Alcohol-benzene solubility (%)	7.5	7.5	7.9	8.0	8.0	8.0
1% NaOH solubility (%)	20.5	21.9	22.5	23.0	23.0	23.5
Moisture (%)	14	20	22	30	35	40
Ash (%)	1.2	1.7	1.7	1.9	2.1	2.3

PULP AND PAPER CHARACTERISTICS

Total pulp yield increases with the age of the culm. The pulp required only 8.91% to 10.49% chlorine for bleaching to develop a brightness of 75% to 84%. The properties of bleached and unbleached pulp change with increasing age of bamboo (Tables 3 and 4). Based on this analysis a 36 months cutting cycle is suggested for pulp production.

UTILIZATION OF *BAMBUSA BAMBOS* AT KALLIPATTY

The strength of bamboo culms, their straightness and lightness combined with hardness, range of sizes, hollowness, and easy working qualities make them suitable for a variety of uses (Shanmughavel and Francis 1993c). Those found in Kallipatty include:

TABLE 3

Physical Strength Properties of Unbleached Pulp

Physical strength properties	Years					
	1	2	3	4	5	6
Burst factor	47.8	48.0	48.2	48.9	49.0	49.1
Tear factor	80	82	84	85	86	86.5
Breaking length (km)	6.7	6.7	6.9	7.2	7.2	7.3
Double folds	85	95	120	150	160	190

TABLE 4

Physical Strength Properties of Bleached Pulp

Physical strength properties	Years					
	1	2	3	4	5	6
Burst factor	37.5	38.0	42.5	42.5	43.5	44.0
Tear factor	63.5	64.9	66.7	68.0	68.9	68.9
Breaking length (km)	4.9	5.0	5.3	5.4	5.4	5.4
Double folds	70	85	90	120	130	140

1. Modern products such as baskets, kitchen containers, wall plaques. Table ornaments and lamp shades.
2. Baskets for the packing and transport of flowers.
3. Scaffolding supports and props in the building sector.
4. Cattle fodder (from the leaves).
5. Toys, hats, wall plates, wall hangers, trays etc.
6. For sericultural practices, bamboo paddles are weaved and used by local farmers.
7. Fuel (from bamboo wastes).

ECONOMICS OF THE PLANTATION

The cost of maintenance and extraction for a six year old plantation are given in Table 5. The cost of raising the entire plantation and maintaining it until 6 year

TABLE 5

Cost of Maintanance and Expenditure Incurred on Extraction of Bamboo

Years	Cost of raising plantation and maintenance (Rs.)	Expenditure incurred on extraction of bamboo (Rs.)	Total Expenditure (Rs.)	Total revenue obtained (Rs.)
1.	11,400	—	11,400	—
2.	6,750	—	6,750	—
3.	5,145	—	5,145	—
4.	6,415	30,000	36,415	56,250
5.	6,320	28,125	34,445	60,500
6.	8,150	50,000	58,150	114,750
Total	44,180	108,125	152,305	231,500

Surplus amount Rs. 79,195

maturity was Rs. 44,180. The extraction cost was Rs. 10,8125. The total revenue realized by the sale of extracted bamboo was Rs. 231,500.

On the whole, 10,750 culms (including 4, 5, 6 year age groups) were obtained from 250 clumps per hectare. The thorns obtained during extraction were also sold. As a rule, a minimum of six mature culms are left in each clump and all tender bamboos less than a year old are left uncut. In practice, however, more culms are left in the clumps, to be on the safe side.

It would seem that a net surplus of Rs. 79,195 was obtained from one hectare of plantation after six years. From general observations of fresh culm production, we can expect higher yields in the next felling cycle. If prices remain the same financial returns are also expected to be as good.

It can be concluded from the simple cost-benefit analysis in Table 6 that the *Bambusa bambos* plantation is not profitable until the end of three years. After this, the benefit/cost ratio (B/C) exceeds 1.0, showing good financial results (Table 6).

Bamboo plantations in Uttar Pradesh, India shared a benefit/cost ratio of 1.7 at a 14.5 percent rate of discount (Chaturvedi, 1986). For a one hectare bamboo plantation in Madhya Pradesh, and the benefit/cost ratio was 1.85 at a 14 percent discount rate. In this study the benefit/cost ratio was 1.51 at a 12 percent discount rate and 1.52 at 14 or 16 percent discount rates (Shanmughavel and Francis, 1993b).

TABLE 6

Cost—Benefit Analysis for Six Year Old *Bambusa bambos* Plantation

Years	Cost (Rs.)	Benefit (Rs.)	Present value under different discount rate					
			12%		14%		16%	
			Cost (Rs.)	Benefit (Rs.)	Cost (Rs.)	Benefit (Rs.)	Cost (Rs.)	Benefit (Rs.)
1	11,400	—	10,032	—	9,804	—	9,596	—
2	6,750	—	5,940	—	5,805	—	5,670	—
3	5,145	—	4,527	—	4,340	—	4,321	—
4	36,415	56,250	32,047	49,500	31,319	48,375	30,591	47,250
5	34,445	60,500	30,311	53,240	29,622	52,030	28,933	50,820
6	58,150	147,750	51,172	100,980	50,009	98,685	48,846	96,390
TOTAL	152,305	234,500	134,029	203,720	130,899	199,090	127,957	194,460

Discount rates: 12% B/C ratio = 1:51, 14% B/C ratio = 1:52, and 16% B/C ratio = 1:52

CONCLUSION

Demand for wood based products like paper, rayon, plywood as well as minor forest products is bound to increase in India, with its population expected to touch one billion by turn of the century. The National Forest Policy of 1988 enunciated that local and industrial demand for forest products should be met increasingly from private lands. The present study shows that the productivity of *Bambusa bambos* plantations is higher than bamboo in natural forests. It is suggested that a cutting cycle of at least 36 months is needed for pulping with the actual period determined with reference to economic criteria. In India, bamboo-based industries have already started to raise plantations on a large scale. The results from this study will be helpful to those engaged in large scale plantation establishment.

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Résumé

Les ressources en bambous sont en train de se réduire avec une vitesse alarmante du fait de la surexploitation et de la diminution de leur habitat naturel. Leur disponibilité ne saura être suivie que si elle est assurée par des plantations. Cet article décrit les résultats obtenus dans une plantation expérimentale de *Bambusa bambos*, une espèce qui s'est avérée idéale pour les plantations à grande échelle. On y aborde les questions de productivité, les caractéristiques de la pulpe et les aspects économiques.

Sumario

El exceso de explotación y el encogimiento de su habitat natural están agotando las fuentes primarias del bambú a un ritmo alarmante. Sólo las plantaciones pueden asegurar una disponibilidad sostenida. En este estudio se describen los resultados de una plantación en prueba de *Bambusa bamboo*. Se ha probado que ésta es una especie ideal para plantaciones a gran escala. Se estudian las características de productividad de la pulpa y los aspectos económicos.

Biomass Models for *Bambusa bambos* - Grown in the Plantations in India

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Abstract

Bambusa bambos has been successfully planted in India to increase the productivity of bamboos. To prepare the biomass models for this species, equations were selected to estimate the green weight of the whole bamboo culm, weights of the branches, leaves, and rhizomes. Diameter and height (DH) were found to be closely correlated with total above ground biomass and therefore selected for the prediction of total biomass.

সারসংক্ষেপ

বাঁশের উৎপাদন বৃদ্ধিকল্পে ভারতে *Bambusa bambos* প্রজাতির বাঁশের চাষ সফলভাবে করা হয়েছে। উক্ত প্রজাতির বায়োমাস মডেল (biomass models) প্রণয়ণের জন্য সম্পূর্ণ কাণ্ডের (whole bamboo culm) কাঁচা অবস্থায় ওজন, কঞ্চি, পাতা ও মোথার ওজন নির্ণয়ের জন্য বায়োমাস সমীকরণ সমূহ (biomass equations) নির্বাচিত করা হয়। ভূ-উপরিস্থ সম্পূর্ণ বায়োমাসের সংগে ব্যাস এবং উচ্চতার (DH) পারস্পরিক সম্পর্ক দেখতে পাওয়া যায় বিধায় সম্পূর্ণ বায়োমাস নির্ণয়ের জন্য উহাদের নির্বাচিত করা হয়।

Key words : *Bambusa bambos*, bamboo, biomass models, India

Introduction

Bamboo is integral to the culture of South - East Asia. India perhaps, has the world's richest resource of bamboo, claiming about 130 species occurring over an area of 9.57 million hectares. This is about 12.8 per cent of the total forest area of the country. However, bamboo resources in their natural habitat are dwindling due to over exploitation, gregarious flowering, shifting cultivation practices and extensive forest fires.

Artificial plantations of bamboos can ensure sustained bamboo productions. Now many countries are going for bamboo plantations to meet the demands of pulp and paper industries. *Bambusa bambos* plantations have recently been raised in India. Biomass studies may be of interest to the growers to assess the performance of species in terms of total biological production.

For biomass estimation regression equations obviate the difficulty of felling of standing trees (George 1977). Literature survey reveals that almost no work has been done on biomass estimation of bamboos from India. However, a report is available for *Gigantochloa scortechnii* from Malaysia (Othman 1992). So regression equations were worked out on the basis of easily measurable parameters utilizing the actual biomass data of *B. bambos* in plantations. Therefore, an attempt was made to prepare biomass models for *B. bambos* in plantations from India.

Materials and methods

Study area

The study area is a six years old plantation of *B. bambos* at Kallipatty, Tamilnadu, India. The area lies between 11° 28′ and 12°E latitude and 76°, 59′ and 77°47′ N longitude. Its altitude is 540 m above mean sea level. The mean annual rainfall is 600 mm and the mean temperature is 31°C. The soil is laterite, red to brown and sandy loam is texture. The soil pH ranges between 7.4 - 7.8. The total soil concentrations in N, P, K, Ca and Mg were 3800, 360, 1600 and 1800 kg per hectare respectively.

Methods

Data were collected by harvesting culms and rhizomes through random sampling. Samples were collected from age groups of 1 to 6 years old. In each age group 15 sample culms were felled. Total 90 bamboo culms were felled for above ground biomass estimation. For estimating below ground biomass a total of 18 rhizomes, three from each group were excavated. After felling of culms, the total height of each culm, diameter at breast height (DBH), basal area, number of nodes were measured and subdivided into leaves, branches, culms and rhizomes. Fresh weight of the components was estimated in the field and sub samples from each component were brought to the laboratory in plastic bags. The sub samples were then oven dried at 103° + 2°C at a constant weight. From the oven dry weight of the samples, the total standing biomass of each age group was calculated by multiplying the total number of the bamboos of different ages with the average dry weight of the sample. The data obtained were fitted to the prediction equations. The following lineraized curvilinear equations of total yield with one variable (diameter) as with two variables (diameter and height) were derived.

(i) Regression equations with single independent variable

Linearized curvilinear model (Whittaker and Woodwell 1968).

$$\log (Y) = a + b \log (x_1)$$
$$\log (Y) = a + b \log (x_2)$$
$$\log (Y) = a + b \log (x_3)$$
$$\log (Y) = a + b \log (x_4)$$
$$\log (Y) = a + b \log (x_5)$$
$$\log (Y) = a + b \log (x_6)$$

Where Y = biomass (kg), x_1 = diameter (D) ; $x_2 = D^2H$; x_3 = BAH; $x_5 = D^2$; x_6 = BA. a, b = are usual constants and log is to the base e.

(ii) Regression equation with two independent variables

$$\text{Log } Y = a + b_1 \log x_1 + b_2 \log x_2$$

Where Y = biomass (kg).
x_1 = diameter; x_2 = height.
a, b are usual constants.

Results and discussion

Simple correlation co-efficient between pairs of the variables, total yield, diameter (D), height (H), diameter and height (DH), square of diameter and height (D^2H), square of diameter (D^2), basal area (BA), basal area and diameter (BAH) were calculated.

All the correlation co-efficient (except for rhizome and grand total biomass) were highly significant (i.e at 1% level of significance). On the basis of the value of determination of co-efficient, the following regression equation was found to be the best:

$$\log y = a + b_1 \log x_1^{(D)} + b_2 \log x_2^{(H)} \text{ (Table 1)}$$

Note : A regression model was fitted between the oven dry weights of tree components as dependent variable, Diameter and height (DH) as independent variable; the model is $\log Y = a + b \log DH$.

Where Y is oven dry weight of tree components, D is diameter in centimeter is the height in metres.

As far as the leaf, branch, culm and total above ground biomass are concerned, the character diameter and height explain 93 to 99 per cent variation. Whereas it is comparatively lower in other components, (rhizome and grand total biomass). This may be mainly due to only 18 bamboos were evaluated for estimation of rhizome biomass and grand total biomass. Therefore, comparatively lesser variation is explained in case of rhizome and grand total biomass.

Table 1 : Regression equation between diameter and height (DH) and dry weight of component (Y) *Bambusa bambos*.

Component	Regression equation	Determination co-efficient (R^2)
Leaf	$\log y = -1.2293 + 1.0850 \log D + 0.1691 \log H$	0.9324
Branches	$\log y = -0.4210 - 0.5014 \log D + 1.2739 \log H$	0.9523
Culms	$\log y = -0.6464 + 0.9394 \log D + 1.0748 \log H$	0.9870
Total above ground biomass	$\log y = -0.3003 + 0.6804 \log D + 1.0440 \log H$	0.9915
Rhizome	$\log y = -0.1109 - 0.8413 \log D + 0.6500 \log H$	0.8180
Grand total biomass	$\log y = -0.0836 + 0.7943 \log D + 0.7586 \log H$	0.8327

Regarding choice of equations there is almost a silent agreement among the workers on use of allometric regression, which employ exponential or logarithmic form of parameters. Ogawa *et al.* (1965) have given several allometric regressions for stem weight, branch weight and root weight, which are dependent upon log – log models. The weight of leaves and height of trees are related to DBH by reciprocal equations. Crow (1971) concluded that the allometric functions proved superior but convenient linear forms could be applied with only a negligible reduction in reliability.

Othman (1992) reported that diameter square and height (D^2H) were found to be closely correlated with total above ground biomass in *Gigantochloa scortechnii*.

Results of this study indicate that variable height and diameter in combination could be used to predict bamboo biomass with reliable precision.

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ABOVE GROUND BIOMASS PRODUCTION AND NUTRIENT DISTRIBUTION IN GROWING BAMBOO (*BAMBUSA BAMBOS* (L.) VOSS)

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Abstract—Above ground biomass production and nutrient distribution in growing Bamboo (*Bambusa bambos* (L.) Voss) from two days old (0.12 m height) to maturity (28.5 m height) were studied over five months. The average daily increase in height was 30 cm and independent of rain. There was a linear increase in the total above ground biomass for all components with the percentage contribution of culm maximum followed by branches, and leaves. Culm recruitment was monsoon dependent. The percentage distribution of N, P, K, Ca and Mg between components varied. Biomass equations were derived to estimate the green weight of the whole bamboo culm, the weights of the branches, leaves, and rhizomes and the relationships between the oven dry weights of various tree components as dependent variables and diameter (D), height (H), diameter and height (DH), square of diameter and height (D^2H), square of diameter (D^2), basal area (B), basal area diameter and height (BH) were determined. Of these, diameter and height (DH) was found to be most closely correlated with total above ground biomass. This was therefore used for the prediction of total biomass. Copyright © 1996 Elsevier Science Ltd.

Keywords—Bamboo; above ground biomass; nitrogen; phosphorus; potassium; calcium and magnesium; *Bambusa bambos*; biomass tables.

1. INTRODUCTION

Bamboo is integral to the culture of South East Asia. Over 75 genera and 1250 species are reported to occur worldwide.[1] India possibly has the world's richest resources of bamboo, with some 130 species occuring over an area of 9.57 million hectares.[2] This is about 12.8% of the total forest area of the country. Even so bamboo resources in their natural habitat are dwindling, due to over-exploitation, shifting cultivation practices and extensive forest fires. Sustained availability can be ensured only by bamboo cultivation. A survey of the literature reveals that work on growth, organic productivity and nutrient distribution of bamboos in its natural habitat[3] is very meagre with almost nothing reported concerning plantations.[4] Studies on the effect of container size on seedling growth of a number of species point to the positive effect of using larger containers.[5,6] The supply of nutrients increases the growth and biomass production in seedlings.[3,7,8]

The main objectives of this investigation were to estimate allocation of biomass to above ground components and to determine the distribution of nutrient content in growing *Bambusa bambos* from two days old (0.12 m height) to maturity (28.5 m height) over a period of five months. An attempt was also made to prepare biomass tables for this species.

2. MATERIAL AND METHODS

2.1. *Study area*

The study covered an area of plantations of *Bambusa bambos* located at Kallipatty, Tamil Nadu State between latitude 11°28′ and 12°E and between longitude 76°59′ and 77°47′N at an altitude of 540 m above mean sea level. This area has red soil with a pH of between 7.4 and 7.8. The maximum soil nitrogen, phosphorus, potassium, calcium and magnesium were 3800, 360, 3600, 1600 and 1800 kg/ha respectively. The mean temperature was 31°C and the mean annual rainfall about 600 mm.

2.2. *Preparation of nursery and planting*

A nursery area of 10 m × 5 m was prepared in a field and filled with a mixture of soil and

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sand in the ratio 3:1. Seedlings, raised by tissue culture techniques were purchased from Chithode, near Erode, Tamilnadu. When they were about 7 cm in height the seedlings were removed from their polythene bags, and transplanted with about 25 to 30 per square metre in a raised nursery bed. irrigated 2 to 3 times a day taking care to avoid excess saturation. The nursery beds were provided with a coconut thatch to protect the seedlings from direct sunlight.

2.3. *Transplantation*

The seedlings in the nurseries were carefully uprooted and transplanted to the field during August 1987 (after about 9 months). The seedlings were planted at 6 m × 6 m spacing in 3 ha at 250 seedlings/ha. The transplanted seedlings were irrigated for two hours on a regular basis in both the morning and the evening. Weeds were removed from the plantation area as and when required. After one year, the plantation was irrigated at 15-day intervals. Care was taken to avoid water-logging and the crop was protected against rodents, grazing and browsing animals.

2.4. *Production of culms*

All transplanted seedlings began to produce rhizomes, which produced a number of lateral culms to form clumps. The productivity of bamboo was assessed by recording the number of new culms produced annually. At a given site the production of new culms was mostly dependent on the culms of the previous year, the degree of congestion and the clump age.[2]

3. GROWTH STUDIES

3.1. *Counting*

The number of clumps and culms presented in the entire study area was counted.

3.2. *Growth measurement*

From the study area, fifteen clumps were selected at random from the sixth year (1993) plantation and identified with paint marking. The number of culms in these selected clumps were counted. New culms sprouting from the selected clumps were taken for growth measurements. In each clump, five newly sprouted culms were marked with paint, totalling 150 observations. On alternate days the height of each culm was measured and, after it had reached 1.37 m height, the diameter at breast height (DBH) was recorded. All observations were made for the basal area girth, DBH and growth in height on all culms.

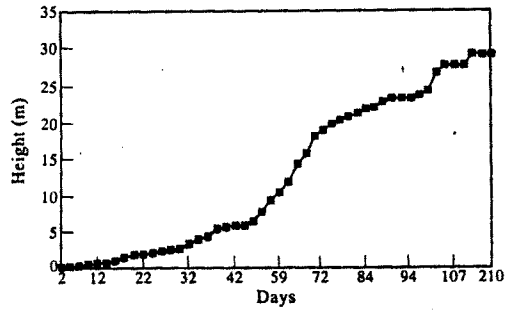

Fig. 1. Height against time. New culm sprouting from the selected clumps were taken for growth measurement. On alternate days, the height of each culm was measured. The values expressed are the average of 3 clumps.

3.3. *Monthly recruitment of culm*

From the same study area, another set of fifteen clumps were randomly selected from the sixth year (1993) plantation for the assessment of monthly recruitment of culm. Every month, the number of newly sprouted culms and their survival were recorded. The observation continued for one full year.

3.4. *Pattern of biomass allocation in growing* Bambusa bambos

The pattern of biomass allocation was studied from the earlier ten selected clumps from which young sprouted bamboo (culm) reached a height of 12 cm. At one-week intervals these young bamboos were harvested and their height recorded. The individual culms, branches and

Table 1. Stand characteristics of Bambusa bamboos plantation

Characteristics	Year					
	1	2	3	4	5	6
Bamboo culms/ha	1250	2250	3000	3500	4000	4250
DBH [cm] (Diameter breast height)	2.3	3.3	4.3	4.8	6.3	8.3
Height [m]	1.44	3.26	9.6	21.8	27.2	28.5

The culm produced from the 1st to 6th year plantation crop was counted per hectare. They were estimated for DBH and height as described in the text. Each value given is the average from three independent experiments.

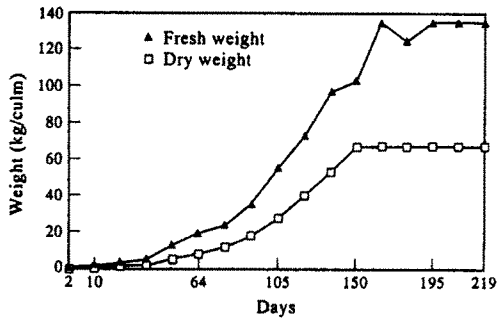

Fig. 2. Dry and fresh weight against time. The accumulation of above ground biomass was studied from the sixth year (1993) plantation starting from initiation (2nd day) to maturation on the days indicated. Each value expressed is the average of three independent experiments.

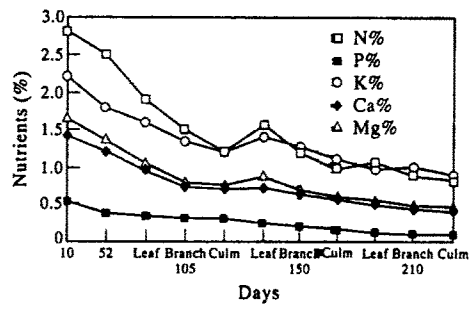

Fig. 3. Change in nutrients with time. The different biomass components were collected from the 10th day onwards. N, P, K, Ca and Mg were estimated by standard methods. Each result is the average of three independent experiments.

leaves were separated and their fresh weight determined in the field. These parts were oven dried at 103° ± 2°C to a constant weight.

4. ESTIMATION OF NUTRIENT ELEMENTS

4.1. *Nitrogen and phosphorus*

Nitrogen and phosphorus was estimated[9] using a Technicon Autoanalyzer–II (Gedko International Ltd, U.K.). The sample was digested in a kjeldatherm digestion system KT 408 (Bonn) at 400°C for 3 hours. One gram sample was digested with 2.5 g potassium sulphate and 5 ml H_2SO_4 made up to 50 ml with distilled water and used for analysis of nitrogen and phosphorus.

4.2. *Potassium, calcium and magnesium*

The nutrients K, Ca and Mg were analysed using an Atomic Absorption Spectrophotometer (Perkin Elmer 5000, U.S.A.) after wet digestion of one gram sample with triple acid mixture (10 ml of conc. HNO_3, 4 ml of $HClO_4$ and 1 ml of conc. HCl). The digested samples were filtered through Whatman No. 42 filter paper and made up to 100 ml with distilled water. This solution was stored and used for analysis.[10]

4.3. *Biomass tables*

Field studies were based on random samplings from 1 to 6 years plantation. For each age group 15 samples culms were felled (90 culms in total) to give total above ground biomass. For estimating below ground biomass, in each age groups 3 rhizomes (total 18) were excavated and their dry weights recorded. The data thus obtained were fitted to the prediction equations. Regression equations and more details of their derivation are given in the final section.

5. RESULTS

5.1. *Growth characteristics*

The appearance of the culm was very slender and the growth of the sprout was initially slow.

Table 2. Pattern of allocation of biomass in growing Bambusa bamboos at the 6th year

Days	Diameter breast height (DBH) [cm]	Height [m]	Leaf dry weight [kg/culm]	Branch dry weight [kg/culm]	Culm dry weight [kg/culm]	Above ground biomass dry weight [kg/culm]
75th day	7.5	20.5	.	2.40	9.70	12.10
96th day	7.5	24.5	.	2.70	15.20	17.90
105th day	8.5	28.0	0.35	3.80	23.65	27.80
120th day	8.5	28.5	0.46	5.10	34.54	40.10
135th day	8.5	28.5	0.71	6.50	46.19	53.40
150th day	8.5	28.5	0.82	8.58	57.10	66.50
165th day	8.5	28.5	0.91	9.39	57.10	67.40
180th day	8.5	28.5	0.92	9.38	57.20	67.50
195th day	8.5	28.5	0.95	9.35	57.10	67.45
210th day	8.5	28.5	0.90	9.10	57.10	67.00
219th day	8.5	28.5	0.94	9.38	57.11	67.44

The culm developed in the 6th year with its components was harvested from the field on the days specified. The wet weight was determined in the field. They were dried at 103° ± 2°C and the moisture free components were used to determine the dry weight.

Table 3. Regression equations between diameter and dry weight of bamboo component y for *Bambusa bambos*

Component	Regression equation	Determination coefficient R^2
Leaf	$\log y = -1.3238 + 1.4917 \log D$	0.9257
Branches	$\log y = -1.1330 + 2.5615 \log D$	0.8362
Culms	$\log y = -1.2471 + 3.5238 \log D$	0.9380
Total above ground biomass	$\log y = -0.8838 + 3.1908 \log D$	0.9353
Rhizome	$\log y = -0.2469 + 0.7075 \log D$	0.5540
Total biomass (above and below ground)	$\log y = -0.5013 + 2.6021 \log D$	0.7745

A regression model was fitted between the oven dry weights of tree components as dependent variable and diameter as independent variable. The model is $\log y = a + b \log D$, where y is the oven dry weight of tree components, and D is the diameter (DBH) in cm.

The daily average increase in height of culm was approximately 30 cm (Fig. 1). Until the 32nd day the internodes were wrapped with sheaths. Thereafter during the next month the culms lost their sheaths. After 50 days, branch buds began to develop. These branch buds increased two to three in number in a circle and were clearly visible after 60 days. Their length began to increase after a further 30 days (i.e. 90 days after their emergence), after which leaf buds began to appear on alternate nodes. These leaves began to mature in the 30 days following their appearance. They varied in length from 15 to 20 cm attaining their full development around the 135th day. Thereafter the culms began to change in hardness and colour. The new culms were produced peripherally from the outer edge of the clump and tended to grow inwards and become entangled amongst the older culms.

5.2. *Monthly recruitment of culm*

The productivity of bamboo was assessed on the basis of the number of new culms produced annually. At a given site, the production of new culms depended mostly on the degree of congestion, the clump age and the rainfall of the previous year. It was noticed that annual increment in culms increased proportionately with age. Only five culms emerged in the first year (1988) after planting. The average number of culms gradually increased in the subsequent year to 9, 14, 15, 16 and 17 per clump. It was noticed that culms emerged in the first year were shorter (1.4 m) in length and thinner (2.3 cm) in diameter at breast height (DBH). Culms produced in subsequent years were distinctly taller and wider in diameter. The average monthly increase in culms for the year 1993 was 17, with maximum initiation during September and November which was the monsoon season. Their survival rate of culms was reduced drastically due to white ants and other physiological causes.

The total number of culms in 1st, 2nd, 3rd, 4th, 5th and 6th year old clump was 1250, 2250, 3000, 3500, 4000 and 4250 respectively (Table 1). The culm height was 1.4 m in the 1st year, 3.2 m in the 2nd year, 9.6 m in the 3rd year, 21.8 m in the 4th year, 27.2 m in the 5th year and 28.5 m in the 6th year. Their corresponding diameters at different ages were 2.3 cm, 3.3 cm, 4.3 cm, 4.8 cm, 6.3 cm and 8.3 cm, respectively.

5.3. *Biomass distribution*

There was a 12-fold increase in culm weight from initial sprouting (0.150 g) to 1 month (1.850 kg/culm). This weight increased as the branches and leaves began to develop.

The total oven dry weight of the culm with its components from its sprouting is shown in Fig. 2. There was considerable variation between dry weight of sample culms and their components. In young sprout the moisture

Table 4. Regression equations between D^2H and dry weight of component y for *Bambusa bambos*

Component	Regression equation	Determination coefficient R^2
Leaf	$\log y = -1.1210 + 0.3330 \log D^2H$	0.9227
Branches	$\log y = -0.8495 + 0.6003 \log D^2H$	0.9190
Culms	$\log y = -0.8115 + 0.8057 \log D^2H$	0.9811
Total above ground biomass	$\log y = -0.4943 + 0.7318 \log D^2H$	0.9842
Rhizome	$\log y = -0.1896 + 0.1753 \log D^2H$	0.6730
Total biomass (above and below ground)	$\log y = -0.1846 + 0.5982 \log D^2H$	0.8307

A regression model was fitted between the oven dry weights of tree components as dependent variable and square of diameter and height (D^2H) as independent variable. The model is $\log y = a + b \log D^2H$, where y is the oven dry weight of tree components, D is the diameter (DBH) in cm and H is the height in m.

Table 5. Regression equations between BAH and dry weight of component y for *Bambusa bambos*

Component	Regression equation	Determination coefficient R^2
Leaf	$\log y = -1.1303 + 0.4400 \log BH$	0.9159
Branches	$\log y = -0.8759 + 0.7990 \log BH$	0.9519
Culms	$\log y = -0.8439 + 1.0705 \log BH$	0.9845
Total above ground biomass	$\log y = -0.5240 + 0.9724 \log BH$	0.9879
Rhizome	$\log y = -0.1966 + 0.2339 \log BH$	0.6952
Total biomass (above and below ground)	$\log y = -0.1796 + 0.7818 \log BH$	0.8231

A regression model was fitted between the oven dry weights of tree components as dependent variable and basal area and height BH as independent variable. The model is $\log y = a + b \log BH$, where y is the oven dry weight of tree components, B is the basal area in cm^2 and H is the height in m.

content was 60–70% up to the development of branch bud. After the initiation of leaves, the moisture content was 50–60%. Later the moisture content was 35–45%.

The biomass allocation of the components in growing *Bambusa bambos* is given in Table 2. It may be noted that 80–85% of biomass was associated with the culm, 15–20% to branch and only 1% was found in leaves.

5.4. *Nutrient composition*

The changes in the nutrient composition during the growth of *Bambusa bambos* is presented in Fig. 3. Nitrogen content in the just sprouted (2nd day) bamboo was found to be 2.85%. This gradually declined to 2.80% on the 10th day and to 2.54% on the 52nd day. On the 52nd day branch buds appeared. On the 105th day leaf bud appeared. The nitrogen content in leaf, branch and culm amounted to 1.90%, 1.55% and 1.21%, respectively. The nitrogen content further declined in all biomass components between the 150th day and 210th day. Thereafter, it remained constant.

The initial value of phosphorus at the sprouting stage was 0.63%. This decreased to 0.54% on the 10th day, and 0.38% on the 52nd day. In branch bud, the phosphorus content was 0.30%, in culm it declined to 0.38% on the 52nd day. On the 105th day the phosphorus contents in leaf, branch and culm were found to be 0.33%, 0.31% and 0.28%, respectively. After the 210th day no further fluctuation in the phosphorus content was noticed.

At the time of sprouting, the potassium content amounted to 2.45%. A declining trend was observed similar to that of other nutrients and reaching 2.20% by the 10th day and 1.80% by the 52nd day. In the branch bud and leaf bud, the levels of potassium were 1.44% and 1.60% respectively, further declining during the growth to reach a constant value.

Higher concentration of calcium were found during the sprouting stage (1.50%). This declined to 1.4% by the 10th day, and to 1.20% by the 52nd day. The initial values of calcium in the branch bud at the 75th day and the leaf bud at the 105th were 0.79% and 0.96%, respectively, declining further to remain constant after 210 days. The final values of calcium at maturity in leaf, branch and culm were found to be 0.51%, 0.43% and 0.41%, respectively.

In the case of magnesium a maximum level of 1.69% was observed during the early sprouting stage, which declined to 1.65% on the 10th day and to 1.38% on the 52nd day. In branch bud and leaf bud the magnesium content was observed as 0.90% and 1.05%, respectively. Similar to other elements, the magnesium content was also found to decline up to 210 days. After this period, the value in leaf, branch

Table 6. Regression equations between height and dry weight of component y for *Bambusa bambos*

Component	Regression equation	Determination coefficient R^2
Leaf	$\log y = -0.9378 + 0.5805 \log H$	0.8891
Branches	$\log y = -0.5557 + 1.0828 \log H$	0.9494
Culms	$\log y = -0.3941 + 1.4310 \log H$	0.9811
Total above ground biomass	$\log y = -0.1175 + 1.3020 \log H$	0.9878
Rhizome	$\log y = -0.1149 + 0.3288 \log H$	0.7471
Total biomass (above and below ground)	$\log y = -0.1296 + 1.0618 \log H$	0.8260

A regression model was fitted between the oven dry weights of tree components as dependent variable and height (H) as independent variable. The model is $\log y = a + b \log H$, where y is the oven dry weight of tree components and H is the height in m.

Table 7. Regression equations between D^2 and dry weight of component y for *Bambusa bambos*

Component	Regression equation	Determination coefficient R^2
Leaf	$\log y = -1.3244 + 0.7460 \log D^2$	0.9255
Branches	$\log y = -1.1337 + 1.2809 \log D^2$	0.8359
Culms	$\log y = -1.2482 + 1.7621 \log D^2$	0.9376
Total above ground biomass	$\log y = -0.8848 + 1.5956 \log D^2$	0.9349
Rhizome	$\log y = -0.2471 + 0.3537 \log D^2$	0.7439
Total biomass (above and below ground)	$\log y = -0.5024 + 1.3013 \log D^2$	0.7941

A regression model was fitted between the oven dry weights of tree components as dependent variable, and the square of diameter D^2 as independent variable. The model is $\log y = a + b \log D^2$, where y is the oven dry weight of tree components and D is the diameter in cm.

and culm was found to be 0.54%, 0.48% and 0.46%, respectively.

6. DISCUSSION

In this study *Bambusa bambos* plants raised with no other associated vegetation did not differ greatly in size or weight. The four-fold gradual increase of culm production by the sixth year is analogous to other bamboos species such as *Bambusa vulgaris*, *B. balcooa*, *B. longispiculata*, *B. tulda* and *Melocanna baccifera* as far as culm formation is concerned.[11] Monsoon dependancy of the plantation was prominent and may be a criterion for forest stands which may have more recruitments during rainy rather than summer. The maximum recruitment of culms seems to be monsoon dependent rather than refluting intermittent showers. In *Gigantochloa ligulata* and *G. levis* similar results have been observed.[12, 13]

In plantation bamboo the culms which emerged in the first year were shorter (1.4 m height) and thinner (2.3 cm) at DBH. Culms produced in subsequent years were distinctly taller and wider in diameter than those produced earlier. This follows the culm recruitment of other bambusa species and *Melocanna baccifera* plantations[11] and in natural stands of *G. levis* and *G. ligulata* except the natural grove of *Phyllostachys reticulata*.[14] In bamboo culms reached their maximum height in about 5 months, analogous to *G. levis* and *G. ligulata*.[14] Under cultivation the average daily height growth is approximately 30.0 cm by the sixth year but this can vary considerably between species depending on the soil conditions and mineral nutrition.[12, 15]

The total standing biomass (t/ha) was calculated on the basis of the number of culms in the 6th year (4250 culms) multiplied by the average total above ground biomass of sample culms (67 kg/culm). The dry matter production of above ground biomass increased progressively and amounted to 286 t/ha over the 6 years. Compared with biomass measurements, the annual yield of air dry bamboo per hectare of 3–4 year plantation was found to be 6–7 for *Bambusa vulgaris* and 1.0 t for *Gigantochloa aspera*.[16] In *Phyllostachys pubscens*, above ground biomass increased from 4.7 kg/m^2 (1985) to 5.6 kg/m^2 (1987). The above ground biomass of *Gigantochloa scortechnii* from Malaysia was 71.9 t/ha in natural stand and 36.36 t/ha in a 3-year old plantation.[17] So in the present study, the accumulation of above ground biomass was found to be higher.

Table 8. Regression equations between D and H and the dry weight of component y for *Bambusa bambos*

Component	Regression equation	Determination coefficient R^2
Leaf	$\log y = -1.2293 + 1.0858 \log D + 0.1691 \log H$	0.9324
Branches	$\log y = -0.4210 - 0.5014 \log D + 1.2739 \log H$	0.9523
Culms	$\log y = -0.6464 + 0.9394 \log D + 1.0748 \log H$	0.9870
Total above ground biomass	$\log y = -0.3003 + 0.6804 \log D + 1.0440 \log H$	0.9915
Rhizome	$\log y = -0.1109 - 0.8413 \log D + 0.6500 \log H$	0.8180
Total biomass (above and below ground)	$\log y = -0.0836 + 0.7943 \log D + 0.7586 \log H$	0.8327

A regression model was fitted between the oven dry weights of tree components as dependent variable, diameter D and height H as independent variables. The model is $\log y = a + b_1 D + b_2 \log H$, where y is the oven dry weight of tree components, D is the diameter in cm and H is the height in m.

Table 9. Regression equations between B and dry weight of component y for *Bambusa bambos*

Component	Regression equation	Determination coefficient R^2
Leaf	$\log y = -1.5805 + 1.7460 \log B$	0.8690
Branches	$\log y = -1.5158 + 2.6986 \log B$	0.7667
Culms	$\log y = -1.8290 + 3.7823 \log B$	0.8926
Total above ground biomass	$\log y = -1.4058 + 3.4183 \log B$	0.8866
Rhizome	$\log y = -0.1966 + 0.2339 \log B$	0.6952
Total biomass (above and below ground)	$\log y = -0.7937 + 2.6398 \log B$	0.7415

A regression model was fitted between the oven dry weight of tree components as dependent variable and the basal area B as independent variable. The model is $\log y = a + b \log B$, where y is the oven dry weight of tree components and B is basal area in cm^2.

7. NUTRIENT COMPOSITION DURING THE GROWTH OF BAMBUSA BAMBOS

In plantation bamboo, the peak concentration of all the nutrients N, P, K, Ca and Mg was at the bud stage and declined during organ expansion stages. All nutrients were concentrated in the actively growing regions.[14,18] A steady decline in N, P, K, Ca and Mg levels, during the growth phases is in accordance with *Eucalyptus hybrid*[19] and in *Quercus leucotrichophora*.[18]

Primary productivity in ecosystem are influenced by several factors such as the availability of nutrients and water. Plants absorb nutrients and transport them to various growing regions, for the production of organic compounds and their incorporation into biomass.[20] Average rates at nutrient accumulation increased rapidly in the early stages of stand development but changes in nutrient content were less marked as the stand age increased[21] corroborate the present study. Higher nitrogen content in the leaves of bamboo is similar to loblolly pine at the early stage of the stands.[22]

8. REGRESSION EQUATIONS

All the correlation coefficients (Tables 3–10) (except for rhizome and total biomass) were highly significant (i.e. at 1% level of significance). On the basis of the value of determination of coefficients, the following regression equation was found to give the best fit (see Table 8).

$$\log y = a + b_1 \log D + b_2 \log H.$$

As far as the leaf, branch, culm and total above ground biomass was concerned, the character DH accounts for 93–99% variation, whereas the degree of correlation was comparatively lower for other components (rhizome and grand total biomass). This may be mainly due to the fact that only 18 bamboos were evaluated for

Table 10. Multiple regression equation of diameter X_1, height X_2, square of diameter X_3, square of diameter × height X_4, basal area X_5, basal area × height X_6 with biomass component y

Tree component	Multiple regression equation	Determination coefficient R^2
Leaf	$\log Y = 1.25 + 22.5 \log X_1 + 0.01 \log X_2 - 10.75 \log X_3 - 0.03 \log X_4 - 0.05 \log X_5 + 0.19 \log X_6$	0.93
Branch	$\log Y = -0.45 + 10.40 \log X_1 + 0.14 \log X_2 + 4.21 \log X_3 + 0.71 \log X_4 - 0.23 \log X_5 + 0.38 \log X_6$	0.95
Culm	$\log Y = -0.77 + 63.90 \log X_1 + 0.09 \log X_2 - 32.92 \log X_3 + 0.22 \log X_4 - 0.10 \log X_5 + 0.70 \log X_6$	0.99
Total above ground biomass	$\log Y = -0.40 + 40.90 \log X_1 + 0.09 \log X_2 - 20.6 \log X_3 + 0.29 \log X_4 - 0.11 \log X_5 + 0.61 \log X_6$	0.99
*Rhizome	$\log Y = 0.36 + 42.9 \log X_1 - 11.60 \log X_2 - 37.3 \log X_3 + 15.9 \log X_4 + 2.62 \log X_5 - 3.68 \log X_6$	0.88
*Total biomass (above and below ground)	$\log Y = 0.33 + 105.2 \log X_1 - 4.99 \log X_2 - 60.4 \log X_3 + 9.34 \log X_4 + 1.35 \log X_5 - 3.68 \log X_6$	0.85

*For 18 Bamboos only.
A regression model was fitted between the oven dry weight of tree components as dependent variable and diameter, height, square of diameter, square of diameter and height, basal area, basal area and height as independent variables. The model is $\log y = a + b + b_1 \log D + b_2 \log H + b_3 \log D^2 + b_4 \log D^2H + b_5 \log BA + b_6 \log BAH$, where y is the oven dry weight of tree components, D is the diameter in cm, H is height in m and B is the basal area in cm^2.

estimation of rhizome biomass and total biomass.

The multiple regression equation developed are presented in Table 10. In comparison with simple linear regression, application of multiple regression was found to be difficult.

From the results obtained in the present study, it was observed that the variables height and diameter in combination could be used to predict bamboo biomass with reliable precision. This is consistent with other results which showed that diameter at ground level could be closely related with both leaf and total biomass in eucalyptus forest vegetations.[23,24] D^2H could be correlated with total biomass in both eucalyptus and pine trees.[25-31]

The use of regression equations in productivity and biomass studies enables realistic estimates to be made. The application of regression equation is comparatively simple as it only requires the measurement of DBH and height. The biomass figures are derived, substituting the logarithmic values of the regression equations and multiplied by the number of trees per hectare.

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BIOMASS ACCUMULATION IN 7, 8 AND 9TH YEAR *BAMBUSA BAMBOS*

by

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Summary

Biomass accumulation in 7, 8 and 9th year *Bambusa Bambos* was studied and compared with its inter species natural stands and between genera of natural and plantation stands. The annual recruitment of culms decreased from 7th year. There was a linear decrease of the total biomass of all compartments from 7th year. In the above ground biomass the percentage contribution was in the order of culms, branches, rhizome and leaves. The accumulation of biomass was found to be 148. 199 t/ha (7 year) 91. 246 t/ha (8 year) and 29.772 t/ha (9 year). The entire biomass productivity depends ultimately on the photosynthetic efficiency of the leaf. The biochemical constituents of bamboo leaves was also studied. The leaf revealed Kranz anatomy, apparently proving a tropical grass, and the biochemical constituents, Chlorophyll, Chlorophyll a, b, a, b ratio, Carotenoides, carbohydrate and starch were inversely proportional with age.

KEY WORDS Biomass accumulation - above ground - below ground - bamboo leaf - biochemical constituents.

Introduction

By far the single - most important item of forest produce used by rural communities of the tropics, from the Cradle to Coffins the bamboo. India possibly has the world's richest resources of bamboo, with some 130 species occurring over an area of 9.57 million hectare. This is about 12.8% of the total forest area of the country and represents 20 percent of India's total production. The diverse bamboos in the natural habitat are dwindling, due to over exploitation, shifting cultivation practices and extensive forest fires. The report on the National Commission on Agriculture brought out some figures about the acurate demand and output of the projected bamboo requirements for 1980 (4.274 million Cu M) and 2000 (7.005 million Cu m) and recommended to cultivate bamboo as plantation crop to bridge the increasing gap between demand and supply. However, we know very little about several aspects of this fascinating plant. Research has increased rapidly in recent years. The growth and productivity has been studies by several workers (Banik 1988, Othaman 1992, Shanmughavel 1995 and Shanmughavel and Francis 1966). The present work is aimed at providing information on accumulation of biomass both above ground and below ground in 7, 8 and 9 year *Bambusa bambos* plantations. The present data has been compared with the previous data of the same plantation of 1 to 6 years age.

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Material and Methods

Study area:

The study covered on area of plantations of *Bambusa bambos* located at Kallipatty, Tamil Nadu State between latitude 11° 28' and 12°E and between longitude 76° 59' and 77° 47' N at an altitude of 540m above mean sea level. This area has red soil with a pH of between 7.4 and 7.8. The maximum soil nitrogen, phosphorus, potassium, calcium and magnesium were 3800, 360, 3600, 1600 and 1800 kg/ha respectively. The mean temperature is 31°C and the mean annual rainfall about 600 mm.

Bamboo Plantation

Since, seeds from bamboo is scanty and possess short period of viability, seedlings obtained from tissue culture was used for raising plantation in this study. The seedlings in the nursery were uprooted carefully and transplanted to the field during August 1987. The seedlings were planted with 6m x 6m spacing in 3 hectares area with 250 seedlings per hectare. The transplanted seedlings were watered two hours regularly in the morning and evening. Weeding was done as and when required. After one year, the plantation was adequately irrigated at 15 day intervals. Care was taken to avoid water logging. The plantation was protected against damage by rodents, grazing and browsing animals. All transplanted seedlings began to produce rhizomes, which produced a number of lateral culms to form clumps.

Counting of Culms/Clump

The number of clumps and culms presented in the entire study area was counted.

Biomass estimation

In order to estimate the total biomass in relation to organic productivity, 15 culms were randomly selected from each age groups of 45. For reasons, of economy the rhizome was excavated only from three samples to a total of nine. After felling, the total height of each culm, diameter breast height (DBH), basal area, and number of nodes were measured and sub divided into leaves, branches, culm and rhizome. Fresh weight of the components was estimated in the field and sub -samples from each component were brought to the laboratory in plastic bags. The sub-samples were then oven dried at 103° C $\pm$ 2° C at constant weight. From the oven-dry weight of the samples, the total standing biomass of each age group was calculated by multiplying the total number of the bamboos of different ages with the average dry weight of the sample.

Biochemical analysis:

The composite leaf samples for estimation of biochemical constituents were collected from 15 individual bamboos of each age group. The leaf was analysed for chlorophyll 7, carotenoides 8, protein 9, total soluble carbohydrates 10 and starch 11. The data was statistically analysed and presented as average of crops.

Results

Counting:

The total number of culms in 7th, 8th and 9th year old clump were 3250, 2750 and 1500 respectively (Table 1). The culm height in 7th year was 20.5m, 16m in 8th year and 8.5 in 8th year. Their corresponding diameters were 5.4 cm, 4.1 cm and 2.8 cm respectively.

Organic Mater in sample trees:-

The height, diameter at breast height (DBH) of the culm with its weight and the individual weight of the branches and leaves for three years are presented in Table-2-4. There were considerable differences within the dry weight of sample trees and their components. In most of the above ground components, the moisture loss ranged between 50 to 60% upon drying. However, in case of below ground parts, it was 40 to 50%. On an average there was about 55% moisture loss with all plant components of all ages. The dry weight of both above and below ground components increased with increase in age up to six years, after which a gradual decrease,was noticed in the 7th, 8th and 9th year. (Table 5)

Culm:

The culm biomass increased by 61.2 times from the 1st year (0.588 kg/culm) to 7th year (35.986 kg/culm), by 42.5 times to 8th year (25.026 kg/culm) and 23.5 times to 9th year (13.860 kg/culm).

Branch:

The branch biomass increased by 16.4 times from the 1st year (0.394 kg/culm) to 7th year (6.493 kg/culm) by 14.4 times to 8th year (5.693 kg/culm), and 10.9 times to 9th year (4.310 kg/culm).

Leaves:

With regard to leaf it increased by 4.3 times from 1st year (0.133 kg/culm) to 7th year (0.584 kg/culm), by 3.7 times to 8th year (0.502 kg/culm), and to 2.3 times to 9th year (0.318 kg/culm).

Total above ground biomass:

When the total biomass of the above ground (culm, branch and leaves) was calculated the weight decrease was concomitant with age and individual parts after 6th years of clump age. The total above ground biomass increased by 39.6 tones from 1st year (1.085 kg/culm to 43.063 kg/culm) to 7th year, by 28.7 times to 8th year (31.221 kg/culm) and by 17 times to 9th year (18.488 kg/culm).

Rhizome:

The rhizome biomass increased by 3.3 times from 1st year (0.750 kg/culm) to 7th year (2.537 kg/culm), by 2.6 times to 8th year (1.960 kg/culm) and by 1.8 times to 9th year (1.360 kg/culm).

Grand total biomass:

The grand total biomass of both below and above ground crop mean average of bamboo increased by 24.8 times from 1st year (1.835 kg/culm) to 7th year (45.600 kg/culm), by 18 times to 8th year (33.181 kg/culm) and by 10.8 times to 9th year (19.848 kg/culm).

Percentage contribution of biomass components:

With regard to contribution of different bamboo components to total shoot weight (total above ground biomass) the culm contributes maximum in all ages. After 6th year, the contribution of culm decreased to 79% in the 7th year, 75% in the 8th year and 72% in the 9th year. However, after 6th year, contribution of branch biomass increased to 5% in the 7th year, 17% in the 18th year and 21% in the 9th year. The percentage contribution of leaf biomass showed only 1% during 7th and 9th year, but 3% during 8th year. The percentage contribution of total above ground biomass and rhizome to the grand total biomass showed considerable variation. It is apparent that, the rhizome biomass to grand total biomass declined from 1st year (41%) to 4% during 6th year. However, during 7th and 8th year increased to 5%. At the age of 9th year, further increased was noticed (6%). (Table - 6).

Grand total biomass (hectare basis)

When all the bamboo biomass components were totaled for the unit area, the grand total biomass (tonnage/hectare) increased by 64.6 times from 1st year (2.294 t/ha) to 7th year (148.199 t/ha) by 39.7 times to 8th year (91.246 t/ha) and by 12.9% to 9th year (29.772 t/ha) (Table - 7,8).

Biochemical analysis

The entire biomass productivity depends ultimately on the photosynthetic efficiency of the leaf. Therefore leaf anatomy, estimation of photosynthetic pigments, total protein carbohydrates and starch were investigated on all ages from 7 to 9 year old worth bamboo leaves. The leaf revealed kranz anatomy and its biochemical constituents inversely portion with age. (Table 9).

Discussion

Counting of culm-clump

The productivity of bamboo is assessed by the number of new culms produced annually. At a given site, the production of new culms mostly dependent on the degree of congestion, clump age and rainfall of the previous year. Bamboo seedlings planted in 1987 at Kallipatty in this study, produced culms in 1988, the next year of plantation. Since, then the culms were treated as 1 year and recording of measurements have been done. The *Bambusa bambos*, produced only 5 culms per clump in the first year. The number of culms increased in the subsequent years and reached maximum (17 culms/clump) during 6th year of age. Number of culm production then slowly decreased from the 7th year and were only 6 in the 9th year of clump age. Similar results were observed in other *Bambusa* species, namely *Bambusa Vulgaris*, *Bambusa balcooa*, *Bambusa longispiculata*, and *Bambusa tulda* and *Melocanna baccifera* at the Forest Research Institute, Bangladesh. Cumulative total culms produced in the clumps of all the *Bambusa* species up to 6th year of age made crowded condition due to short (7 - 12 cm) heck pachymorph rhizome system. This crowded and congested condition created a scarcity of room for the new emerging culms and also increased competition among them for survival. Probably due to this reason culm production subsequently decreased from the 6th year in this study.

Biomass accumulation:

In the present study, generally the above ground biomass as well as dry weight of biomass components increased concomitant with diameter at breast height (DBH) and height of the culm which contributed a major share to the total biomass. Ageing improves above ground biomass, which is accumulated maximum at the age of six, subsequently, a decrease in the accumulation of biomass was noticed. In natural forests, the culm weight of *Phyllostachys edulis*, *Phyllostachys reticulata* varied between 13 and 44 kf/culm respectively and their height and diameter to age also was lesser than their counterparts of plantation stands. The culm fresh weight of *Dendrocalamus strictus*, *Bambusa bambos* and *Melconna baccifera* tends to be more than *Phyllostachys* species, but with same diameter. Since the culm height of the former three species are taller, their fresh weight with the same diameter and thick walls tend to be heavier then *Phyllostachys* species (Ueda 1960).

With regard to the percentage contribution of biomass components to the above ground biomass, the plantation age was an important factor. The percentage contribution of leaf decreased with increasing age. This perhaps reflect that bamboos are deciduous. When they fall off from the base of culms and branches, new ones replace without any additional number. No definite trend was observed in case of branch. They are produced as the culm elongated in height and the total amount of branches appear to be fixed with the growth of the culm. Several plantation crops such as *Eucalyptus teriticornis* 14 *E. hybrid* 15, and *E. globulus* 16,17, fall in line in this regards.

Compared with biomass measurements the annual yield of air-dry bamboo per ha. of 4 year old plantation was found to be 7 t/ha-7 for *Bambusa Vulgaris* and 1t. for

Gigantochloa aspera 18. The above ground biomass of *Gigantochloa scortechrii* from Malaysia was 71.9 t/ha-1 in natural stand and 36 t/ha-1 in a three year old plantation. Compared with these studies, present estimate was found to be much higher.

Biochemical analysis:

The significance of chlorophyll content in characterizing the productive potential of various crops was repeatedly stressed. The entire biomass productivity depends ultimately on the photosynthetic efficiency of the leaf. The bamboo leaf revealed kranz analomy, apparently proving a tropical grass and its chlorophyll, chlorophyll a.b and a, b ratio, Carbohydrates and starch were inversely proportional with age. The results showed high correlation between the biomass productivity and chlorophyll content analogous to mango cultivars (Hedge and Bawachkar 1983).

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TABLE - 1 STAND CHARACTERISTICS OF BAMBUSA BAMBOS PLANTATION

Characteristics	Year		
Bamboo Clums/ha		2750	1500
Diameter at breast height (DBH)	5.4 ± 0.12	4.1 ± 0.20	2.8 ± 0.25
Height (m)	20.5 ± 1.0	16 ± 1.20	8.5 ± 1.15

The culm produced from 7 to 9 year plantation crop was counted per hactare. The values expressed are average of five independent observations.

TABLE 2. ORGANIC MATTER DISTRIBUTION IN 7TH YEAR BAMBUSA BAMBOS

Sample culm No.	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (cm)	Leaf	Branches	Culm	TAGB	Rhizomes	GTB
1	7	6.0	5.5	20.5	0.600	6.400	35.200	42.200	2.400	44.600
2	7	5.9	5.0	20.4	0.550	6.900	36.100	43.550		
3	7	6.5	5.5	20.0	0.590	6.500	36.500	43.590		
4	7	5.0	5.5	20.5	0.650	7.000	37.100	44.750		
5	7	6.0	5.4	20.5	0.550	6.600	38.100	45.250		
6	7	5.5	5.4	20.4	0.490	7.100	35.100	42.690		
7	7	6.5	5.5	20.5	0.500	5.900	35.700	42.100		
8	7	6.0	5.4	20.5	0.650	7.200	36.000	43.850	2.600	46.450
9	7	6.5	5.5	20.3	0.550	6.500	35.100	42.150		
10	7	6.0	5.5	20.3	0.600	6.100	36.200	42.900		
11	7	6.5	5.4	20.5	0.550	5.900	34.900	41.350		
12	7	6.0	5.5	20.5	0.600	6.900	36.100	42.600		
13	7	6.0	5.4	20.5	0.650	6.100	35.000	41.750		
14	7	6.5	5.5	20.0	0.600	6.800	36.700	44.100		
15	7	6.0	5.5	20.0	0.650	6.500	36.00	43.150	2.600	45.750

TABLE 3. ORGANIC MATTER DISTRIBUTION IN 8TH YEAR BAMBUSA BAMBOS

Sample culm No.	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (cm)	Leaf	Branches	Culm	TAGB	Rhizomes	GTB
1	8	5.0	4.0	16.5	0.450	5.100	28.500	34.050	2.000	36.050
2	8	5.0	4.0	16.8	0.400	5.500	23.500	29.400		
3	8	5.5	4.3	17.0	0.500	6.600	23.100	30.200		
4	8	5.0	4.5	16.0	0.450	5.500	26.500	32.450		
5	8	5.3	4.0	16.5	0.500	5.800	20.100	26.400		
6	8	5.0	4.0	16.5	0.490	5.500	25.800	31.790		
7	8	5.0	4.0	16.0	0.500	6.000	26.100	32.600		
8	8	5.4	4.5	16.5	0.590	5.500	27.200	33.290		
9	8	5.0	4.1	16.0	0.550	5.700	26.500	32.750	2.100	34.850
10	8	5.0	4.0	16.5	0.500	6.000	24.700	31.200		
11	8	5.0	4.2	16.4	0.550	5.500	23.500	29.550		
12	8	5.3	4.5	16.0	0.500	5.000	18.800	24.300		
13	8	5.0	4.0	16.5	0.510	6.100	27.200	33.810		
14	8	5.0	4.0	16.5	0.550	5.600	25.800	31.950		
15	8	5.3	4.5	16.0	0.550	6.000	28.100	34.650	1.800	36.450

TABLE 4. ORGANIC MATTER DISTRIBUTION IN 8TH YEAR BAMBUSA BAMBOS

Sample culm No.	Age (yrs)	Basal area (cm)	Diameter (cm)	Height (cm)	Leaf	Branches	Culm	TAGB	Rhizomes	GTB
1	9	3.5	2.8	9.5	0.300	4.00	10.100	14.400	1.660	16.000
2	9	3.5	2.8	9.0	0.300	4.150	13.500	17.950		
3	9	3.5	3.0	8.5	0.350	5.000	15.100	20.450		
4	9	4.0	3.0	8.5	0.400	4.000	14.200	18.600		
5	9	4.0	3.0	8.5	0.300	4.100	13.000	17.400		
6	9	3.5	2.8	8.0	0.325	4.300	10.000	14.625		
7	9	3.5	2.8	8.5	0.300	4.700	10.500	15.500		
8	9	4.0	3.0	8.5	0.290	4.100	14.100	18.490		
9	9	4.0	3.0	9.0	0.300	4.00	13.500	17.800	1.300	19.100
10	9	3.5	2.8	9.0	0.350	4.200	15.100	19.650		
11	9	3.5	2.8	8.5	0.300	5.000	15.500	20.800		
12	9	4.0	3.0	8.0	0.300	4.500	16.100	20.900		
13	9	3.5	2.8	8.5	0.310	4.500	15.100	19.910		
14	9	3.5	2.8	8.5	0.350	4.000	15.000	19.350		
15	9	3.5	2.8	8.5	0.300	4.200	14.100	18.600	1.200	19.800

TABLE - 5. AVERAGE BIOMASS OF SAMPLE BAMBUSA BAMBOS.

AGE	Leaf biomass		Branch biomass Culm biomass				Total above ground biomass		Rhizome biomass		Grand total biomass	
Years	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)
7	1.260	0.584	13.100	6.493	69.400	35.986	83.760	43.073	4.700	2.537	88.460	45.6
8	1.110	0.502	12.550	5.693	45.200	25.026	58.860	31.221	3.850	1.960	62.710	33.1
9	0.980	0.318	10.810	4.310	30.800	13.860	42.590	18.488	2.500	1.360	45.090	19.8

Different components of bamboo such as culm, leaves and rhizome were collected individually their fresh weight was taken in the field. They were dried in the laboratory for dry weight determination. The values are expressed as average of three independent experiments.

TABLE-6. PERCENTAGE OF INDIVIDUAL CULM COMPONENTS

Age (Years)	Average diameter (cm)	Average Height (m)	Leaf biomass (%)	Branch biomass (%)	Culm biomass (%)	Rhizome biomass (%)
7	5.4	20.5	01	15	79	05
8	4.1	16.0	03	17	75	05
9	2.8	8.5	01	21	72	06

The percentage contribution of individual culm components were calculated. the cum contributes the maximum biomass followed by branch, rhizome and leaves.

TABLE 7. Production od biomass on unit area basis (tonnes/ha)

Age (years)	Culm diameter (cm)	Culm height (cm)	Basal area (cm)	Number of culms	Number of nodes	Leaf	Biomass t/ha Branches	Culm	Total above ground biomass	Rhizome biomass	Grand total biomass
1	2.3	1.4	3.1	1250	7	0.166	0.493	0.698	1.356	0.938	2.294
2	3.3	3.2	4.0	2250	16	0.668	1.897	6.795	9.360	3.150	12.510
3	4.3	9.6	5.0	3000	37	1.122	17.115	29.250	47.487	4.980	52.467
4	4.8	21.8	6.1	3500	86	1.862	27.160	92.750	121.772	6.055	127.827
5	6.3	27.2	8.3	4000	98	3.544	33.940	187.224	224.708	9.600	234.308
6	8.3	28.5	10.1	4250	103	4.021	39.886	242.730	286.637	11.220	297.857

The culm, branches, leaves and rhizome were collected individually and after determining their weight at the field, were oven dried at 103 ± 2 C in the laboratory. Their moisture free dry weight was determind. their individual weight are expressed as t/ha. The values expressed are average of three independent experiments.

TABLE 8. PRODUCTION OF BIOMASS ON UNIT AREA BASIS (t/ha).

Age (Years)	Culm Height (m)	Basal area (cm)	DBH (cm)	Number of culms/ha	Number of holds	Biomass t/ha			Total above ground biomass	Rhizome biomass	Grand total biomass
						Leaf	branch	culm			
7	20.5	6.0	5.4	3250	81	1.898	21.102	116.954	139.954	8.245	148.199
8	16.0	5.4	4.1	2750	66	1.380	15.655	68.821	85.856	5.390	91.246
9	8.5	3.6	2.8	1500	44	0.477	6.455	20.790	27.732	2.040	29.772

The Culm, branches, leaves and rhizome were collected individually, and after determining their fresh weight at the field, were oven dried at 103 ± 2 C in the laboratory. Their moisture free dry weight was determined. The averate biomass values of the sample trees were multiplied with the number of culms in hectare, to calculate the unit area biomass. The values expressed are average of three independent experiments.

TABLE 9. BIOCHEMICAL CHARACTERISTIC OF BAMBOO LEAF

Age (Years)	Total Chlorophyll (m/g)	Chlorophyll a (M/g)	Chlorophyll b (M/g)	Chlorophyll a, b, ratio	Carotenoides (Mg/g)	Protein (Mg/g)	Carbohydrate (Mg/g)	Starch (Mg/g)
7	340	160	173	0.92	48.00	5.60	6.10	454.89
8	323	147	162	0.90	47.40	5.13	5.73	433.24
9	304	131	149	0.88	46.70	4.85	5.45	410.39

The Values expressed are average of three independent experiments.

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SUSTAINABLE DEVELOPMENT OF NON-WOOD FOREST PRODUCTS OF THE SUNDARBAN RESERVED FOREST: AN INTEGRATED APPROACH

Laskar Muqsudur Rahman[1]

The Sundarban Forests of Bangladesh is the largest single tract of mangrove forest in the world having an area of 577,000 ha that has the distinction of being the first mangrove forest in the world to be brought under scientific management. Until recently the Sundarbans had been seen primarily as a wood-producing unit and other products were usually referred to minor forest products. Now time has come to set objectives for strategies aimed at improving production of not only timber but also non-timber products in a sustainable manner. Nypa palm, fish and honey have been given substantial attention but more from the point of view of revenue earning potential than in terms of improving sustainable production for the benefit of underprivileged local people. Existing management systems do not make sufficient provision for such management and at present there is a serious imbalance in institutional arrangements, structures, research, monitoring, staff training and control mechanisms. The collection and processing arrangements are primarily done by two sectors, viz. The Government primarily through the Forestry Department (FD) and small scale private entrepreneurs. The Forest Department has no specialized section for handling non-wood forest products. It is done as an additional responsibility. Some steps have been taken by private sector entrepreneurs on a very small scale and on a necessary purely commercial basis. Attention by responsible authorities is now necessary.

Keywords: Mangroves, Tourism, Management, Sustainable

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PLANTATION BAMBOO FOR SUSTAINABLE PRODUCTIVITY

P. Shanmughavel[1]

Over-exploitation and shrinkage of their natural habitat is depleting the bamboo resources at an alarming rate. Sustained availability can be ensured only by plantations. This paper describes the results from a trial plantation of *Bambusa bambos*. This proved to be an ideal species for large-scale plantations. Productivity, pulp characteristics and economic aspects are discussed.

Keywords: Natural bamboo, depletion, sustained availability, plantation bamboo.

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STUDIES ON MONTHLY RECRUITMENT OF CULMS IN *BAMBUSA BAMBOS* (L.) VOSS.

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Abstract

Studies on monthly recruitment of culms in *Bambusa bambos* were made for one year during 1993. It revealed that, culm recruitment was monsoon dependent and was enhanced by a pre-shower preceding the onset of monsoon. The annual recruitment of culms indicated a steady increasing trend from first year (1250 culms/ha.) to sixth year (4250 culms/ha.). Based on the recruitment and performance of culms, harvesting year suggested.

Introduction

The bamboos which are giant, woody, tree-like grasses, have a long history as an exceptionally versatile and widely-used resources. And yet, over-exploitation associated with growing human population, destruction of tropical forests and increased demands on the resource for industrial uses, especially by the pulp and paper industry, has resulted in wide scale decimation of bamboo stocks from vast forests of bamboo in South and South East Asia in the last decades of this century, and are left with the current situation of acute scarcity. Sustained availability can be ensured only by resorting to elaborate bamboo cultivation (Shanmughavel and Francis, 1993).

The productivity of bamboo was assessed by the number of new culms produced annually (Sharma, 1988). Therefore, the main objective of this investigation was to assess the recruitment of new culms every month and its survival rate. This was calculated for one year and is reported in this paper.

Material and Methods

Study Area : The study area of plantation of *Bambusa bambos* is located at Kallipatty between 11° 28' and 12° E of Longitude and 76° 59' and 77° 17' N Longitude. Its altitude is 540 m above msl. This area has red soil. Soil pH was between 7.4 and 7.8. The maximum soil nitrogen, phosphorus, potassium, calcium and magnesium 3800, 360, 3600, 1600 and 1800 kg/ha. respectively. The mean temperature was 31° C. Mean annual rainfall was about 600 mm.

Preparation of Nursery and Planting : Nursery area of 10 m x 5 m was prepared in the field and filled with a mixture of soil and sand (3:1). Seedlings, raised by tissue culture techniques were purchased from Chithode, near Erode, Tamil Nadu. When they were about 7 cm in height, seedlings were removed from their polythene bags, and about 25-30 seedlings were transplanted in one square metre of raised nursery bed and irrigated 2-3 times a day taking care to avoid excess saturation. Nursery beds were provided with a coconut thatch to protect the seedlings from direct sunlight.

Transplantation : The seedlings from the nursery were carefully uprooted and transplanted to the field during August (after about 9 months). The seedlings were planted at 6 m x 6 m spacing in 3 hectare area with a total of 250 seedling/ha. The transplanted seedlings were irrigated two hours regularly both in the morning and evening. Weeds were removed from the plantation area as and when required. After one year, the plantation was adequately irrigated at 15 days interval. Care was taken to avoid waterlogging and protected against rodents, grazing and browsing animals.

Production of Culms : All transplanted seedlings began to produce rhizomes. From these rhizomes lateral culms were emerging which are the causatives for the total biomass yield. The number of culms developed from the rhizome total constituted to a clump. The productivity of bamboo was assessed by the number of new culms and mostly depended on the culms of the previous year, the degree of congestion and the clump age.

Growth Studies

Counting : The number of clumps and culms presented in the entire study area were counted.

Growth Measurement : From each hectare fifteen clumps were selected at random from the sixth year plantation and identified with paint marking. Number of culms present in these selected fifteen clumps were counted. New culms sprouting from the selected clumps were taken for growth measurements. In each clump, five newly sprouted culms were marked with paint, totalling 150 observations. On alternate days the height of each culm was measured and only after the attainment of 1.37 m height, the diameter at breast height (DBH) was recorded. All observations were made for the basal area, girth, DBH and growth in height on all culms.

Monthly Recruitment of Culm : From the same study area, another set of fifteen clumps were randomly selected from the sixth year old plantation for the assessment of monthly recruitment of culms. Every month, the number of newly sprouted culms and their survival were recorded. The observation continued for full one year.

Results

Counting : The total number of culms in 1st, 2nd, 3rd, 4th, 5th and 6th year old clump was 1250, 2250, 3000, 3500, 4000 and 4250 respectively (Table - 1).

Monthly recruitment of culm : The productivity of bamboo was assessed by the number of new culms produced annually. At a given site, the production of new culms mostly depended on the degree of congestion, clump age and rainfall in the previous year. It was noticed that annual recruitment of culms increased proportionately with age. Only five culms emerged in the first year (1988) after planting. The average number of culms gradually increased in subsequent years to 9, 14, 15, 16 and 17 per clump. The monthly recruitment of culms for the year 1993 is presented in Table-2. The perusal of the Table reveals that maximum recruitment of culms took place during September - November which was the monsoon season. An average of 17 culms were produced from one clump during 1993. However, their survival rate was reduced drastically due to white ants and other physiological causes at a later stage.

Table-1: Stand characteristics of *Bambusa bambos* plantation

Characteristics	Year					
	1	2	3	4	5	6
Bamboo Culms/ha.	1250	2250	3000	3500	4000	4250
DBH (cm)	2.13±0.22	3.13±0.22	4.2±0.25	4.9±0.20	6.2±0.25	8.2±0.25
Height (m)	1.44±0.37	3.26±0.20	9.6±0.76	21.6±1.49	27.3±0.52	29.0±0.56

The culm produced from 1st to 6th year plantation crop was counted per hectare. They were estimated for DBH and height as described under materials and methods. The values expressed are average from three independent experiments.

Table-2 : Monthly recruitment of culms/clump

Month	Sample Clump Number																									
	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S
January	3	-	4	-	4	1	1	1	2	-	3	1	4	-	4	1	3	1	3	1	4	1	3	-	4	1	1	-	1	1
February	4	1	4	-	2	-	2	-	3	1	4	1	3	1	3	1	4	1	4	1	4	-	4	1	3	-	2	1	2	1
March	3	1	3	1	3	1	3	-	4	1	3	-	4	2	5	1	2	-	3	1	3	-	5	2	4	1	3	1	3	1
April	2	-	2	-	3	-	2	1	6	1	2	-	3	-	4	-	3	-	4	-	-	-	6	1	5	2	-	-	4	1
May	2	-	2	-	4	1	4	1	3	-	3	-	4	-	3	-	4	1	3	-	-	-	3	-	-	-	-	-	-	-
June	3	-	4	2	4	2	6	2	2	-	4	2	3	2	2	1	5	2	4	1	3	1	4	1	3	1	4	2	3	1
July	5	-	5	2	6	3	8	3	6	3	6	3	4	2	4	3	8	4	6	3	4	1	6	3	7	3	5	1	6	3
August	4	1	5	2	7	3	6	2	8	3	9	4	6	2	6	3	9	3	9	2	5	2	8	3	5	3	6	3	4	2
September	8	4	6	3	8	2	6	4	7	4	6	3	4	1	6	3	3	1	7	3	6	3	8	4	6	4	4	3	6	4
October	6	3	4	1	4	2	3	1	3	-	4	1	6	4	3	2	4	2	4	1	6	4	6	3	3	2	2	1	4	3
November	6	3	3	1	3	1	3	-	4	1	3	1	4	2	6	2	3	1	3	1	4	2	4	1	4	2	3	1	3	1
December	5	1	4	2	3	1	2	2	3	1	3	1	3	2	5	2	2	1	6	2	3	1	3	-	3	1	4	2	4	2
Total culms	16		14		17		17		15		17		18		19		17		16		15		19		20		15		20	

Fifteen clumps were randomly selected from the sixth year plantation for the assessment on monthly-recruitment of culms and their survival were recorded. It revealed the maximum recruitment of the culms took place during September-November, which was the monsoon season. An average of 17 culms were produced from one clump, during the year 1993.

C - Number of newly sprouted culms
S - Survival

Discussion

Growth characteristics : In the current study *Bambusa bambos* plantation raised under identical climatic and edaphic conditions, with no other associate, did not differ greatly in size or weight. About four fold gradual increase of culm production at sixth year is analogous to other bamboo species such as *Bambusa vulgaris, B. balcooa, B. longispiculata, B. tulda* and *Melocanna baccifera* in their culm formation (Banik 1988). Monsoon dependence of the plantation was prominent and may be a criteria for forest stands which may have more recruitments during rainy rather than summer. The maximum recruitment of culms seems to be monsoon dependent rather than intermittent showers. *Gigantochloa ligulata* and *G. levis* (Kondas *et al.*, 1983; Othman 1992) follow such recruitment of new culms.

In *Bambusa bambos* plantation, the culms emerged in the first year were shorter (1.4 m height) and thinner (2.3 cm) at DBH. Culms produced in subsequent years were distinctly taller and wider in diameter than those produced in previous year. The present findings are similar to culm recruitment of other *Bambusa* species and *Melocanna baccifera* plantations (Banik 1988) and natural stands of *B. levis* and *G. ligulata* (Othman 1993) except the natural grove of *Phyllostachys reticulata*. In *Bambusa bambos* culms reached their maximum height in about 5 months, analogous to *B. levis* and *G. ligulata* (Othman 1993). Under cultivation the average daily growth increment in height is approximately 30.0 cm at sixth year which might vary considerably between species depending on the soil conditions and mineral richness of soil (Raghavan 1964; Kondas *et al.*, 1983)

Harvesting : Based on the foregoing results, it can be concluded that no culm of less than three year should be cut unless it is a cleaning and spacing out operation. However, the farmer will not wait for 7-8 years to harvest the bamboo and would like to have his returns according to his needs and as soon as possible. In the light of above facts, a 36 months of harvesting is suggested.

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The silviculture and management of the Bamboo - Bambusa bambos

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Traditionally, bamboo has been referred to as a minor forest produce. However the status of bamboo has changed considerably and it is rapidly emerging as an important plant group in many forestry programmes. During the past few decades, several Asian countries have embarked on large-scale cultivation of economically important species. This paper reports the silviculturally correct method of planting and management of the Bambusa bambos.

1. Seedling obtained from tissue culture methods were used. (Seeds possess short period of viability and the procurement of seeds also difficult). The large sized polythene bags 20 cm x 30 cm are filled with clean soil, sand and manure in the ratio 2 : 1 : 1. About 15 to 20 plants were planted in each polythene avoid over saturation. Seedlings were kept in polythene bags for one month.

2. The nursery is raised in shades.

3. Each polythene bag contains 15 to 20 seedling. The number of Rhizomes may vary from 4 to 5. These set of Rhizomes is not singled out (or) sorted but the entire thing in one polythene bag is planted in the field.

4. The seedlings in the nursery were uprooted carefully and transplanted to 45 cm x 45 cm pits in the fields at a spacing 6 cm x 6 cm. (one weak prior planting, the pits were treated with 0.01 percent aldrex and 0.05 percent bavistin to prevent termit and fungal attack respectively).

5. The planting was completed before the monsoon got fully set in.

6. To provide better initial growing environment to the seedlings, the upper of halves of the pits was filled up with an mixture of 25 gram vijay complex 17 : 17 : 17 per pit, while lower halves were filled up with the original soil.

7. Protection against damage by rodents, grazing and browsing animals is to be carriedout.

8. The profuse watering is done but over watering is avoided.

9. The transplanted seedlings produces rhizomes, which develop new rhizomes that produce lateral culms, which are the chief causatives for the total biomass yield. The number of culms developed from the rhizome totally constituted to a clump.

10. At a given site, the production of new culms is depended on the culms of the previous year, the degree of congestion and the clump age. The average annual recruitment of culm generally increased year after year. The culms produced during first year is shorter in length and smaller in diameter, but culms, from subsequent years will be longer in length an bigger in diameter.

11. The rhizome development is not peripheral as generally believed. Rhizomes may develop in any direction and the culme may appear any where in the clump provided over head light is available for the emergence of the culm. It is only in congested clumps that the new culms appear to grow at the periphery. The new can even be seen in the middle of the clump.

12. New bamboo culms are produced each year. Older culms should, therefore, be harvest each year. Culms older than two years take little part in the growth of new culms. Retention of culms older than two years is, therefore, not needed for the production of new culms. Culms older than three years are fully mature for the desired end use. The following rules should therefore be applied for getting high productivity of the desired quality of culms.

13. All bamboo culms three yearsolder should be harvested.

14. Harvesting should preferably be along each year.

15. Where congestion has already set in, the congested culms must be removed even if it leaves only the current year culms.

16. Where the young culms are twisted from the top they should be cut so that the new culms grow freely.

17. No felling operations should be carried out from July to October.

18. Mounding (or) heaping earth around the bamboo culms should be carriedout after every felling of culms.

19. Bamboo clump should in no case be clear felled. The Clear felled clump generally degenerate into a bushy form.

The above mentioned silviculture and management practices can be used as guidelines for takingup large scale plantations on suitable site.

Thrips Management in onion

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Onion *Allium cepa L.* is commercially cultivated vegetable crop grown throughout the country. Thrips *(Thrips tabaci)*, a key pest causing severe yield loss upto 32 per cent. The nymphs and adults congregate in dense masses in the narrow spaces between leaf sheaths and stems, it feeds by lacerating the epidermis of leaves and lapping the exuding plant sap. The affected leaves show silvery white blotches which later became brownish and get distorted from tips, wilt downward and dry, finally the bulb size get reduced, are the important symptoms of damage. Nymphs are pale yellowish in colour and adults with fringed wings. Eggs period is 5-10 days, nymphal period is 6-12 days with two moults. The pupation takes place inside the soil. The total life cycle is completed within 14-16 days in summer, 24-26 days in winter. High temperature with a long dry spell weather favoured for its rapid multiplication. To manage the past spray neem oil 3 percent formulation on 30 days after sowing, avoid use of synthetic pyrethroids which favour the multiplication of thrips, spray insecticides either with monocrotophos 2 ml/lit. Twice at the interval of 15 days, using a high volume sprayer. Insecticides or neem oil spraying is advised during evening hours of the day in order to suppress the pest population very effectively.

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Biomass production in an age series of *Bambusa bambos* plantations

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Abstract

The biomass production in an age series of *Bambusa bambos* plantations was estimated, and compared with its interspecies natural stands and between genera of natural and plantation stands. There was a linear increase of the total biomass of all compartments with the age of the plantation. In the above-ground biomass, the percentage contribution of culms(81%), branches(14%) and leaves(1%) was 96%, whereas in the below-ground rhizome contribution was 4%. The total biomass ranged from 2.3 t DM ha^{-1} (1 year) to 297.9 t DM ha^{-1} (6 year). The mean annual biomass production was 49.6 t DM ha^{-1}, over the 6 year period. The mean periodic increment and net primary production was highest in the 5th year during which a peak of 124.1 t DM ha^{-1} yr^{-1} in net primary production was obtained. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Biomass production; *Bambusa bambos*; Mean periodic increment; Net primary production

1. Introduction

The bamboos are woody tree-like grasses, have a long history as an exceptionally versatile and widely used resource. Over 75 genera and 1250 species occur in the world [1]. Bamboo resources in their natural habitat have decreased considerably due to overexploitation, shifting cultivation practices, and extensive forest fires. Compared with the vast forests of bamboo found in South and Southeast Asia at the beginning of this century, there is acute scarcity now. Efforts are, therefore, underway to research into cultural and agronomic techniques which will boost bamboo production so that raw material in sufficient quantity can be made available to farmers, rural households and large industries. In view of this an experimental trial of *Bambusa bambos* was conducted in Tamil Nadu, India. A survey of the literature reveals that work on growth and biomass productivity of *Bambusa bambos* is minimal [1,2] and practically nothing is published on plantations. Hence, a thorough study has been carried out on the growth and productivity of *Bambusa bambos* growing over 1–6 years.

2. Materials and methods

2.1. Study area

The study area of plantation *Bambusa bambos* is located at Kallipatty near Sathyamangalam between 11°28′ and 12°E of latitude and 76°59′ and 77°47′N

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longitude. Its altitude is 540 m above MSL. This area has red soil with pH between 7.4 and 7.8. The maximum soil nitrogen, phosphorus, potassium, calcium and magnesium were 3800, 360, 3600, 1600 and 1800 kg ha^{-1}, respectively. The mean temperature was 31°C. Mean annual rainfall was about 600 mm.

2.2. Nursery and plantings

A nursery area of 10 m × 5 m was prepared in the field and filled with a mixture of soil and sand (3:1). Seedlings, raised by tissue culture techniques were purchased from Vesta Farm, Chithode, near Erode, Tamil Nadu. When they were about 7 cm in height, 25–30 seedlings were transplanted in 1 m^2 of raised nursery bed, and irrigated 2–3 times a day, taking care to avoid excess saturation. Nursery beds were provided with a coconut thatch to protect the seedlings from direct sunlight.

2.3. Transplantation

The seedlings in the nurseries were carefully uprooted and transplanted to the field during August 1987. The seedlings were planted at 6 m × 6 m spacing in 3 ha area with a total of 250 seedlings ha^{-1}. The transplanted seedlings were irrigated for 2 h in both morning and evening. Weeds were removed from the plantation area as and when required. After 1 year the plantation was irrigated at 15 day intervals [3]. Care was taken to avoid water logging and protected against rodents, grazing and browsing animals.

2.4. Production of culms

The transplants produced rhizomes from which lateral culms emerged and constituted to a clump. The productivity was assessed by the number of new culms produced annually. At a given site, the production of new culms was mostly dependent on the productivity of the culms of the previous year, the extent of canopy overlap and the clump age.

2.5. Biomass estimation

Fifteen culms were randomly selected and cut from each age group for a total of 90. For economy reasons, rhizomes were excavated only from three samples for a total of 18. After felling, the total height of each culm, diameter at breast height (DBH), basal diameter and number of nodes were measured and sub-divided into four main components, leaves, branches, culm(bole) and rhizome. A total of 18 rhizomes (three from each year's plantation) were excavated for the determination of underground biomass by making a trench around the culm. Fresh weight of the components was estimated in the field and a sub-sample from each component was oven dried at 103 ± 2°C to a constant weight.

Total standing biomass (t DM ha^{-1}) was calculated from the average dry weights of the samples. The annual biomass production (total biomass divided by age), mean periodic production (the difference between biomass of two stands in an age sequence divided by the age interval) and net primary productivity were estimated [4].

2.6. Litter estimation

Nine litter plots sized 1 × 5 m were laid down randomly throughout the sample plot. The litter plots were permanently marked by enclosing the area with nylon thread, which lasted throughout the study period. The contents in the litter plots were sampled completely by the end of every month and separated into leaf litter and twig litter. Fresh weight was estimated in the field and a sub-sample was oven-dried at 80°C to a constant weight. From the sample oven dry weight the total dry weight of the litter was calculated [5].

3. Results

3.1. Biomass production

There was linear increase in the biomass of all compartments with the age of the plantation (Table 1). The culm height increased from 1.4 to 28.5 m in 6 years concomitant with the expansion in diameter from 2.3 to 8.3 cm. The total biomass also increased from 2.3 (1 year) to 298.9 t DM ha^{-1} (6 year).

Leaf weight increased from 0.2 t DM ha^{-1} in 1 year to 4.0 t DM ha^{-1} in 6 year (24.2 times higher). The branch biomass increased from 0.5 to 39.9 t DM ha^{-1} in 6 year, a factor of 80.9.

The total above-ground biomass (culm, branch and leaves) increased from 1.3 to 286.6 t DM ha^{-1}, a factor of 211.3. However, the below-ground biomass (rhizome) increased from 0.9 to 11.0 t DM ha^{-1}, which was 11 times higher.

3.2. Percentage contribution of different components

With regard to the contribution of different plant components to total shoot weight (total above-ground biomass) the culm contributes the maximum in all age groups. It increased from 30% in 1 year to 85% in 6 year (Table 1).

The percentage contribution of branches to total shoot, showed considerable variation among the ages, varying between 14 and 33%. The contribution of leaves to total shoot weight gradually decreased from 7% in 1 year to only 1% during 6 year. The contribution of above-ground biomass to total biomass increased from 59 to 96% in the 5 and 6 years and thus the rhizome biomass declined from 41 to 4%.

3.3. Mean biomass production, net periodic increment and net primary production

The mean annual biomass accumulation increased with stand age. But the data on mean periodic increment and net primary production showed that the rate of biomass accumulation was highest in the 5th year, during which a peak of 124.1 t DM ha^{-1} net primary production was obtained (Table 2).

4. Discussion

4.1. Above and below ground components

Total above-ground biomass as well as dry weight of biomass components increased concomitant with DBH and height of the culm which contributes the major share to the total biomass. Ageing improves the above-ground biomass which is accumulated to a maximum at age 6. In natural forests, the culm weight of *Phyllostachys edulis*, *Phyllostachys reticulata* varied between 44 and 13 kg, respectively, and their height and diameter to age also was lower than their counterparts in plantation stands. The culm fresh weight of

Table 1
Production of biomass (the percentage contribution of individual culm components are presented in parentheses)[a]

Age (years)	Av. culm diameter (cm)	Av. culm height (m)	Av. basal area (cm^2)	Av. number of culms (per ha.)	Number of nodes (per culm)	Leaf (t DM ha^{-1})	Branches (t DM ha^{-1})	Culm (t DM ha^{-1})	Litter (t DM ha^{-1})	Total above-ground biomass (t ha^{-1})	Rhizome biomass (t ha^{-1})	Grand total biomass (t ha^{-1})
1	2.3	1.4	3.1	1250	7	0.2(7)	0.5(21)	0.7(32)	ND	1.4	0.9(40)	2.3
2	3.3	3.2	4.0	2250	16	0.7(5)	1.9(15)	6.8(55)	ND	9.4	3.1(25)	12.5
3	4.3	9.6	5.0	3000	37	1.1(2)	17.1(33)	29.2(56)	ND	47.5	4.9(9)	52.4
4	4.8	21.8	6.1	3500	86	1.9(2)	27.1(20)	92.7(73)	15.4	137.2	6.0(5)	143.2
5	6.3	27.2	8.3	4000	98	3.5(2)	33.9(14)	187.2(80)	17.6	242.3	9.6(4)	251.9
6	8.3	28.5	10.1	4250	103	4.0(1)	39.8(14)	242.7(85)	20.3	306.9	11.2(4)	318.2

[a]Av. — average, ND — not determined.

Table 2
Mean biomass production, net periodic increment and net primary production (t ha^{-1})[a]

Age (years)	1	2	3	4	5	6
Mean annual production	2.3	6.2	17.5	31.9	48.9	49.6
Mean periodic annual production	2.3	10.2	39.9	75.4	106.5	63.5
Litter fall	ND	ND	ND	15.4	17.6	20.3
Net primary production	ND	ND	ND	90.8	124.1	83.8

[a]ND — not determined.

Dendrocalamus strictus, *Bambusa arundinacea* and *Melocanna baccifera* tends to be more than *Phyllostachys* species, but with the same diameter. Since the culms of the former three species are taller, their fresh weight with the same diameter and thick walls, they tend to be heavier than *Phyllostachys* species [1]. In comparison with the above three species under natural forests, bamboo under plantations showed 19–85% heavier culm weights.

The percentage contribution of culm biomass components to the above-ground biomass varied between 30 and 85% dependent on plantation age. The percentage contribution of leaves decreased with age. The leaves are deciduous, when they fall from the base of the culms and branches, new ones replace the old without any increase in number. No definite trend was observed in the case of branches. They are produced as the culm elongates in height and the total amount of branches appear to be fixed with the growth of the culm. The percentage contribution of rhizomes to total biomass [13] correlates with leaves. Several plantation crops such as *Eucalyptus tereticornis* [6], *E. hybrid* [5], *E. globulus* [7–9], *E. camaldulensis* [10] are similar to bamboo in this regard.

4.2. Total biomass

The total standing biomass (t DM ha^{-1}) was calculated from the total number of the bamboos of different ages. The dry matter production of the above and below ground biomass increased progressively with age to 251.9 t DM ha^{-1} (5 year) and 318.2 t DM ha^{-1} (6 year). Compared with biomass measurements the annual yield of air-dry bamboo per ha of 3–4 year old plantation was found to be 6.07 t for *Bambusa vulgaris* and 1.0 t for *Gigantochloa aspera* [11]. The above-ground biomass of the plantation is 85% higher. The above-ground biomass of *Gigantochloa scortechnii* from Malaysia was 71.9 t DM ha^{-1} in a natural stand and 36.4 t DM ha^{-1} in a 3-year-old plantation [11]. This is lower than the 3-year-old plantation stand (47.5 t DM ha^{-1}) found here. Compared with other fast growing tree species, 8.6 t DM ha^{-1} in 4-year-old *Eucalyptus globulus* [7], 47 t DM ha^{-1} in 5-year-old *Leucaena leucocephala* [12] and 87 t DM ha^{-1} in 6-year-old *Pinus carribaea* [13], the present biomass estimates are found to be 7–30% higher.

4.3. Below and above-ground biomass ratio

The below and above-ground biomass ratio of the 1- and 6-year-old plantations varied from 0.69 to 0.04. One year old plants develop extensive vast lateral roots to provide water and nutrients. In older plants (6 year old) the aerial parts were obviously more developed than the under ground parts. In an 8-year-old plantation of *Populus deltoides* the ratio was 0.1 [14]. The ratio was 0.30 in *Tectona grandis* and 0.28 in *Terminalia tomentosa* among 15–20-year-old plants of natural dry deciduous teak forest [15]. The 5-year-old *E. camaldulensis* and 15-year-old *E. camaldulensis* plantation had ratio of 0.43 and 1.12, respectively [19].

4.4. Net primary production

The net primary production and mean annual biomass accumulation depend on stand age. In the 5-year-old plantation bamboo, 124.1 t DM ha^{-1} yr^{-1} was attained, which is 7–10% higher than tropical and subtropical pine plantations (12 t DM ha^{-1} yr^{-1}) [16–18].

4.5. Dry-organic matter density

The density of dry organic matter of bamboo was estimated by dividing the total above-ground biomass with the average height [11]. The dry-organic matter density was within the range of 0.9–10.0 kg m^{-3}. This shows that the dry-organic matter density of *Bambusa bambos* found to be much higher than those already reported in other bamboo species. The dryorganic matter density of *Gigantichloa scortechnii* was about 0.54–0.55 kg m^{-3} [11], and 0.52–0.88 kg m^{-3} in other bamboo species [19].

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BIOMASS PRODUCTION IN TEN YEARS OLD PLANTATION OF *BAMBUSA BAMBOS*

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Introduction

Bamboos are nature's unique gifts to mankind. It is the most universally useful plant known to mankind and approximately 2.5 billion people, mostly the poor in developing countries, depend on it for a wide range uses and livelihoods. Over-exploitation has depleted the natural bamboo resources to alarming levels. Sustainable resource management has, so far, not been possible mainly because of insufficient knowledge, skills and practices in both indigenous and scientific management systems. The application of appropriate silvicultural techniques for bamboo can lead to large increases in production. Bamboo because of its suitability, is being raised in plantations in several countries. The results of biomass production in ten years old *Bambusa bambos* plantation raised at Kallipatty, India has been reported in this paper.

Study Area

The study area of *Bambusa bambos* plantation is located at Kallipatty, between 11° 28' and 12° E Latitude and 76° 59' and 77° 59' and 77° 47'N Longitude. Its altitude is 540 m above MSL. This area had red soil. The maximum soil Nitrogen, Phosphorus, Potassium, Calcium and Magnesium were 3800, 360, 3600, 1600 and 1800 kg/ha respectively. The mean temperature was 31°C. Mean annual rainfall was about 600 mm.

Plantation Details

The seedlings were planted at 6 m x 6 m spacing with a total of 250 seedlings/ha. All transplanted seedlings began to produce rhizomes. From these rhizomes lateral culms were emerging which are the chief causatives for the total biomass yield. The number of culms developed from the rhizome totally constituted to a clump. The productivity of bamboo was assessed by the number of new culms produced annually. The total number of culms in 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 9th and 10th year old clump was 1250, 2250, 3000, 3500, 4000, 4250, 3250, 2750, 1500 and 900 respectively. The maximum culm height was 29 m in the sixth year and the minimum was 1.4 m in the first year. Their corresponding diameter was 8.2 cm and 2.1 cm respectively.

Biomass Estimation

In order to estimate the total biomass in relation to organic productivity fifteen culms were selected randomly from each age group of plantation. For economy reasons, rhizome was excavated only from three samples. After felling, the total height of each culm, DBH, basal diameter, number of nodes were measured and subdivided into four main components : leaves, branches, culm and rhizome. Three rhizomes from each year plantation were excavated for determination of underground biomass by making a trench around the culm. Fresh weight of the components were estimated in the field and sub-sample from each component was brought to the laboratory in plastic bags. The sub-samples were then oven dried at 103 ± 2°C to a constant weight. From the oven dry weight of the samples, the total standing biomass (t/ha) of each age group was calculated by multiplying the total number of the bamboos of different ages with the average dry weight of the sample.

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Table-1: Production of biomass on unit area basis (tonnes ha) in *Bambusa bambos*

Age (years)	Culm diameter (cm)	Culm height (m)	Basal area (cm)	Number of culms/ha	Number of nodes	Leaf	Biomass branches t/ha	Culm	Total above ground biomass	Rhizome biomass	Grand total biomass
1	2.3	1.4	3.1	1250	7	0.166	0.493	0.698	1.356	0.938	2.294
2	3.3	3.2	4.0	2250	16	0.668	1.897	6.795	9.360	3.150	12.510
3	4.3	9.6	5.0	3000	37	1.122	17.115	29.250	47.487	4.980	52.467
4	4.8	21.8	6.3	3500	86	1.862	27.160	92.750	121.772	6.055	127.827
5	6.3	27.2	8.3	4000	98	3.544	33.940	187.224	224.708	9.600	234.308
6	8.3	28.5	10.1	4250	103	4.021	39.886	242.730	286.637	11.220	297.857
7	20.5	6.0	5.4	3250	81	1.898	21.102	116.954	139.954	8.245	148.199
8	16.0	5.4	4.1	2750	66	1.380	15.655	68.821	85.856	5.390	91.246
9	8.5	3.6	2.8	1500	44	0.477	6.455	20.790	27.732	2.040	29.772
10	7.4	3.0	2.5	900	37	0.246	2.853	11.430	14.529	1.143	15.672

The culm, branches, leaves and rhizome were collected individually and after determining their fresh weight in the field, were oven dried at 103 ± 2°C in the laboratory. Their moisture free dry weight was determined. Their individual weight are expressed as t/ha. The values expressed are average of three independent experiments.

Table-2: Organic matter distribution in 10th year *Bambusa bambos*

Sample culm No	Age	Basal Area (cm)	Diameter (cm)	Height (m)	Biomass kg/culm Leaf	Branches	Culm	TAGB	Rhizome	GTB
1	10	3.0	2.7	7.5	0.270	3.100	12.800	15.900	1.270	17.170
2	10	3.0	2.5	7.5	0.275	3.250	12.800	16.325		
3	10	2.7	2.5	7.5	0.270	3.100	12.000	15.525		
4	10	3.0	2.5	7.0	0.270	3.100	13.000	16.370		
5	10	2.5	2.5	7.0	0.275	3.400	13.000	16.675		
6	10	3.0	2.9	7.5	0.270	3.700	12.900	16.870		
7	10	3.0	2.5	7.0	0.275	3.100	12.700	16.075		
8	10	3.0	2.5	7.4	0.275	3.200	12.800	16.275		
9	10	2.5	2.5	7.5	0.274	3.000	11.900	15.174		
10	10	2.7	2.5	7.5	0.275	2.975	11.900	15.150	1.270	16.420
11	10	3.0	2.5	7.0	0.270	3.000	12.800	15.070		
12	10	3.0	2.5	7.0	0.275	3.000	12.800	16.075		
13	10	3.0	2.7	7.5	0.270	3.000	11.900	15.170		
14	10	3.0	2.7	7.0	0.270	2.975	12.100	15.345		
15	10	3.0	2.5	7.5	0.275	3.100	13.000	15.375	1.270	17.645

Table-3: Average biomass of sample *Bambusa bambos*

Age	Leaf biomass		Branch biomass		Culm biomass		Total above ground biomass		Rhizome biomass		Grand total biomass	
(Year)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)	Fresh weight (kg)	Dry weight (kg)
1	0.332	0.133	0.980	0.394	1.470	0.588	2.782	1.085	1.250	0.750	4.032	1.835
2	0.655	0.297	1.837	0.843	6.711	3.020	9.239	4.160	2.333	1.400	11.572	5.560
3	0.831	0.374	12.677	5.705	21.666	9.750	35.174	15.829	3.018	1.660	38.192	17.489
4	1.064	0.532	15.520	7.760	53.000	26.500	69.584	34.790	3.460	1.730	73.044	36.522
5	1.775	0.886	16,970	8.485	93.600	46.800	112.345	56.171	4.800	2.400	117,145	58.571
6	1,895	0.946	18.430	9.385	114.840	57.113	135.160	67.444	5.280	2.640	140.168	70.084
7	1.260	0.584	13.100	6.493	69.400	35.986	83.760	43.073	4.700	2.537	88.460	45.600
8	1.110	0.502	12.550	5.693	45.200	25.026	58.860	31.221	3.850	1.960	62.710	33.181
9	0.980	0.318	10.810	4.310	30.800	13.860	42.590	18.488	2.500	1.360	45.090	19.848
10	0.890	0.274	9.520	3.170	26.300	12.700	36.710	16.144	2.100	1.270	38.270	17.414

Different components of bamboo such as culm, branch, leaves and rhizome were collected individually and their fresh weight was taken in the field. They were dried in the laboratory for dry weight determination as described under materials and methods.The values are re-expressed as average of three independent estimates.

Biomass Production

The data on production of biomass recorded in this study is presented in Table-1 to 3. It revealed that there was linear increase of the total biomass of all compartments up to sixth years of plantation, and then gradual decrease in biomass accumulation was noticed. In the above ground biomass, the percentage contribution of biomass components was in the order of culms, branches and leaves. In the below ground biomass rhizome occupied a percentage similar to leaves. In conclusion, the demand for wood based products like paper, rayon, plywood as well as minor forest products is bound to increase in India, with its population expected to cross over a billion in the early of this century. The present study show that the productivity of *Bambusa bambos* plantations is higher than bamboo in natural stands. It is suggested that a cutting cycle of at least 36 months is needed for pulping with the actual period determined with reference to economic criteria. In India, bamboo based industries have already started to raise plantations on a large scale. The results from this study will be helpful to those engaged in large scale plantation establishment of bamboos.

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BIOMASS ACCUMULATION AND NUTRIENT CONCENTRATION IN *BAMBUSA VULGARIS* SCHRAD.EX.J.C. WENDL.

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ABSTRACT

This paper describes the results from a 4-year-old trial plantation of *Bambusa vulgaris* Schrad.ex J.C.Wendl. grown in Goundampalayam area, Coimbatore, India. The growth, biomass accumulation and nutrient concentration were studied. The number of culms produced per clump varied from 28 to 46 their maximum length, and diameter at breast height (DBH) were 20 m and 3.5 cm respectively. The number of nodes per culm ranged between 20 to 34. The total biomass ranged from 277.3 t. DM ha^{-1} to 500.6 t. DM ha^{-1} with an average percent contribution of culms (66%), branches (26%) and leaves (3%). The ground biomass of rhizome contributed 5% to the total above and below ground biomass. The percent distribution of nutrients in different biomass components varied: The ordering of major element concentrations was K > N > Mg > Ca > P in branch, culm, rhizome but in leaves it was found to be N > K > Mg > Ca > P. The maximum amount of all nutrients was accumulated in the culms, followed by branches, rhizomes and leaves. *Bambusa vulgaris* proved to be a useful species for raising in plantations.

Key words: Bambusa vulgaris, biomass accumulation, India, nutrient concentration.

INTRODUCTION

Bamboo is an arborescent grass. For centuries, bamboos have played an important role in daily life of the people in many countries, particularly in Asia (Liese 1985). India has the world's richest resources of bamboo, about 130 species occurring over an area of 10.05 million hectares or about 12.8% of the total forest area of the country (Sharma 1987). However, bamboo in its natural habitat is dwindling due to over exploitation, gregarious flowering, shifting cultivation and extensive forest fires. Now, sustained availability can be ensured only by intensive bamboo cultivation (Shanmughavel 1995). More recently, curiosity about these peculiar plants with their widespread distribution, rapid rate of growth and multipurpose uses has grown (Tewari 1992: Shanmughavel *et al.* 1997).

Observations on the growth and development of forest bamboos were made by Hasan 1975, Caracallus *et al.* 1988. Studies on the effect of container size on seedling growth performance of *Bambusa arundinaceae* indicated that shoots and

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length of the plant were not influenced by container size. (Chacko and Jayaramanan 1988). Performance of bamboo seedlings in the nursery with varying spacing and fertility levels has been studied (Kondas *et al.* 1973: Suzuki and Narita 1995: Kim *et al.* 1976, Patil and Patil 1988). However reports on growth and nutrient dynamics of bamboos in social forestry is limited. (Seshadri 1985, Balaji 1991, Shanmughavel and Francies 1995). Therefore a study was carried out on the growth performance and nutrient concentration of the bamboo (*Bambusa vulgaris* Schrad.ex.J.C.Wendl.) plantations raised in the Goundampalayam area, Coimbatore, India.

MATERIALS AND METHODS

The study area

The study site is located at Goundampalayam, Coimbatore, India, at an altitude of 426 MSL, and on 12° N of latitude and 77° 47′ E. longitude. The climate of the area is monsoon. The maximum temperature and rainfall was 31.5°C and117.5 mm respectively. The area has red soils with P^H between 7.5 to 8.4 and in electrical conductivity of 0.2mScm. The maximum soil (sub layer) nitrogen, phosphorus, and potassium were 19.8, 7.6, and 15 kg/ha respectively.

The seedlings in the nurseries were carefully transplanted to the field at 6 m × 6 m spacing with a total of 250 seedlings/ha. The transplanted seedlings were irrigated for two hours regularly both in the morning and evening. Weeds were removed from the plantation area as and when required. After one year, the plantation was adequately irrigated at 15 day intervals. Care was taken to avoid water logging and the plantation was protected against grazing and browsing animals by fencing.

All transplanted seedlings began to produce rhizomes. From the rhizomes lateral culms emerged. The number of culms developed from the rhizome totally constituted to a clump.

Measurements

At age four years, five clumps from the study area's 250 clumps were randomly selected and identified with paint. The number of culms (single bamboo stems) in these selected clumps was counted and measurements of each diameter at breast height (DBH), length and number of nodes were taken. (Table 1) Table 1 near here

Three culms were randomly selected from each of the 5 trial clumps in order to estimate the total clump biomass. For reasons of economy, only five (one in each trial clump) rhizomes were excavated for the determination of below ground biomass by making a trench around the culm. After felling and subdividing into leaves, branches, culm and rhizome, the fresh weights of these components were taken in the field; sub samples from each component were brought to the laboratory

TABLE 1

Growth characteristics of *Bambusa vulgaris*

Year	Growth Characteristics	Sample Clumps				
		A	B	C	D	E
4	Total number of clumps/ ha	250				
	Average Culms/ Clump	30	28	36	41	46
	Average Length (m)	10 ± 3	13 ± 7	20 ± 4	14 ± 4	11 ± 3
	Average dbh (cm)	3.0 ± 1.0	3.5 ± 1.0	3.0 ± 0.5	2.8 ± 1.0	2.5 ± 1.0
	Number of Nodes (no)	34 ± 9	30 ± 7	33 ± 4	20 ± 3	23 ± 4

The values are expressed as averages of three independent experiments. (±) = Standard error

in plastic bags. The sub-samples were oven dried at 102 ± 2° C to a constant weight. From the oven, dry weight of the samples, the total standing dry weight of each clump group was calculated by multiplying the total number of the bamboos in each sample clump with the average dry weight of the sample rhizome and culm.[1]

ESTIMATION OF NUTRIENTS

The nitrogen and phosphorus were estimated (Armstrong *et al.* 1967) using a TECHNICON AUTOANALYZER—II (Gedco International Ltd). The nutrients K, Ca, and Mg, were analyzed using an atomic absorption spectrophotometer (Perkin-Elmer 5000,USA) (Issac and Johnson 1975).

RESULTS

The numbers of new culms per clump and the number of their nodes ranged from 8 to 46 and 20 to 34 respectively. Similar results were observed by Liese (1985), Othman (1992) and Shanmughavel and Francis (1996).

The dry leaf biomass ranges from 0.65 to 0.84 kg/culm. The branch and culm dry biomass ranged from 7.9 to 9.1 kg/culm and 10.3 to 13.4 kg/culm. The rhizome and grand total biomass varied from 0.90 to 1.60 and 19.9 to 24.3 kg/culm, respectively (Table 2).

The culm contributes 29–33%—to total shoot weight of the different plant components in all the clumps. The contributions of leaf, branch and rhizome biomass were 15–23%, 20–23% and 24–36% respectively (Table 3).

[1]This procedure was criticized by reviewers and sampling culms of different diameters recommended. Editor

TABLE 2

Biomass allocation of *Bambusa vulgaris* (Kg/Clump)

Age in Years	Sample Clump	Biomass (Kg/culm)			Total above ground biomass (Kg)	Rhizome biomass (Kg)	Grand total biomass (Kg)
		Leaves	Branch	Culm			
4	A	0.84 ± 0.40	8.29 ± 0.13	11.30 ± 0.35	20.43 ± 0.76	0.90 ± 0.35	21.33 ± 0.42
	B	0.73 ± 0.30	9.10 ± 0.34	13.40 ± 0.43	23.23 ± 0.37	1.10 ± 0.35	24.33 ± 0.14
	C	0.68 ± 0.49	8.40 ± 0.22	11.64 ± 0.41	20.72 ± 0.32	1.30 ± 0.43	22.02 ± 0.45
	D	0.72 ± 0.35	7.90 ± 0.33	10.30 ± 0.31	18.92 ± 0.25	0.99 ± 0.11	19.91 ± 0.34
	E	0.65 ± 0.10	8.60 ± 0.39	12.70 ± 0.46	21.95 ± 0.44	1.60 ± 0.18	23.55 ± 0.42

The values are expressed as averages of three independent experiments.

TABLE 3

Percentage contribution of individual culm

Sample clump	Leaf biomass	Branch biomass	Culm biomass	Rhizome biomass
A	23	22	31	24
B	18	22	33	27
C	17	21	29	33
D	20	23	29	28
E	15	20	29	36
AVERAGE	18.6	21.6	30.2	29.6

The average biomass values of the sample bamboos were multiplied by the total number of culms in a hectare to calculate the dry biomass per hectare[2] (Table 4). Leaf biomass ranged from 63 to 75 t DM ha^{-1}, branch biomass from 62 to 99 t DM ha^{-1}, culm biomass from 85 to 146 t DM ha^{-1}(Table 4), and rhizome biomass from 68 to 184 t DM ha^{-1}. The total above ground dry biomass ranged from 208 to 320 t.DM ha.The grant total biomass ranged from 277 to 500 t.DM ha.

The average nutrient concentrations in the four components of bamboo are given in Table 5. The concentration of nutrients in the various biomass components was generally in the order of leaf > branch > culm > rhizome, with the nutrient elements in the order of K > N > Mg > Ca > P except for the leaf, which had the nutrient elements in the order of N > K > Mg > Ca > P .

The total nutrient content was obtained by multiplying the biomass components by their respective nutrient concentration. The nutrient content in the above and

[2]NB The results must be treated with caution as the limited extent of the sampling may have introduced bias. Editor

TABLE 4

Production of biomass (t DM ha^{-1})

Sample clump	Leaf biomass	Branch biomass	Culm biomass	TAGB	Rhizome biomass	Grand total biomass
A	63.0 ± 1.5	62.1 ± 1.9	84.7 ± 2.4	209.8 ± 3.4	67.5 ± 0.3	277.3 ± 0.4
B	51.1 ± 1.1	63.7 ± 2.1	93.8 ± 2.7	208.6 ± 2.4	77.0 ± 0.3	285.6 ± 0.1
C	61.2 ± 1.3	75.6 ± 2.3	104.7 ± 2.3	241.5 ± 3.9	117.0 ± 0.4	358.5 ± 0.4
D	73.8 ± 1.5	80.9 ± 2.1	105.5 ± 1.9	260.2 ± 4.1	101.0 ± 0.4	361.2 ± 0.4
E	74.7 ± 2.1	98.9 ± 2.4	146.0 ± 3.2	319.6 ± 4.5	184.0 ± 0.1	503.6 ± 0.4

TABLE 5

Average nutrient concentration in biomass components (%) of *Bambusa vulgaris*

Nutrient	Leaf	Branch	Culm	Rhizome
N	0.65 ± 0.05	0.63 ± 0.10	0.57 ± 0.40	0.43 ± 0.10
P	0.08 ± 0.01	0.07 ± 0.01	0.06 ± 0.01	0.05 ± 0.01
K	0.60 ± 0.06	0.75 ± 0.30	0.76 ± 0.30	0.63 ± 0.03
Ca	0.24 ± 0.30	0.24 ± 0.20	0.19 ± 0.20	0.17 ± 0.10
Mg	0.30 ± 0.10	0.31 ± 0.10	0.23 ± 0.10	0.21 ± 0.10

TABLE 6

Average nutrients retained in biomass components of *Bambusa vulgaris* (Kg/ha)

Nutrients	Leaf biomass	Branch biomass	Culm biomass	TAGB	Rhizome biomass	GTB
N	420.5 ± 4.3	480.0 ± 4.7	612.7 ± 5.1	1513.2 ± 9.8	469.9 ± 3.2	1983.1 ± 1.5
P	51.7 ± 1.1	53.3 ± 1.9	64.6 ± 1.4	169.6 ± 1.9	54.6 ± 2.1	224.2 ± 2.4
K	388.2 ± 3.8	571.5 ± 5.2	817.0 ± 5.8	1776.7 ± 1.0	688.0 ± 6.1	2464.7 ± 1.1
Ca	155.2 ± 2.1	182.8 ± 2.4	204.2 ± 4.1	542.2 ± 2.1	185.8 ± 4.1	728.0 ± 7.9
Mg	194.1 ± 2.3	236.2 ± 2.9	247.2 ± 5.4	677.5 ± 4.9	228.9 ± 5.2	906.4 ± 8.4

below ground biomass were in the order of K > N > Mg > Ca > P. Per hectare the maximum amount of all nutrients was found in the culm followed by branches, rhizome and leaves.

DISCUSSION

The productivity of bamboo may be assessed on the basis of the number of new culms produced per clump annually. At a given site, the production of new culms depends mostly on the degree of congestion, the clump age and the rainfall of the

previous year (Shanmughavel and Francis 1996). The annual yield of air dry Gigantochloa aspera bamboo per hectare of a 4 year old plantation was found to be 1 t DM ha^{-1} for (Chinte, 1965), 297 t DM ha^{-1} for *Bambusa* bambos (Shanmughavel 1995), 4 t DM ha^{-1} *Phyllostachys pubscens* (Qiu and Maoyi 1987 and Huang, 1987). The above ground biomass of *Gigantochloa scortechnii* from Malaysia was 71.9 t DM ha^{-1} in a natural stand and 36.67 t DM ha^{-1} in 3 years old plantation (Othman 1992). In the present study the accumulation of biomass was found to be even higher (277 to 500 t /DM ha^{-1}). This may be due to a high culm recruitment under this regime with irrigation.

The nutrient elements in the leaf were in the order of N > K > Mg > Ca > P. The results are in general agreement with results for *Dendrocalamus hamiltoni* (Toky and Ramakrishnan 1983) *Bambusa balcooa*, Dendrocalamus strictus and Thyrostachys olivery (Tewari *et al.* 1994), and *Bambusa* bambos (Shamughavel 1995). In *Bambusa khasiana*, the order was K > N > Ca >Mg > P (Rao, and Ramakrishnan 1989).

The concentrations of potassium was the highest among the nutrients. Bamboo plays an important role in the conservation of potassium, because of its capacity for rapid uptake and accumulation. Of the total nutrient content, potassium alone contributed 39%. Thus in bamboo plantations, the element potassium is predominant over N, Ca, Mg, and P; the effect of burning bamboo on the soil nutrients is analogous to the effect of slash and burn agriculture in central Amazon (Brinkman and Nasimento, 1973) in a Costa Rican wet forest site (Ewel *et al.* 1981) in South America, and in *Dendrocalamus strictus* (Toky and Ramakrishnan 1983) in India. However the total accumulation of potassium per hectare in this 4 year old *Bambusa vulgaris* of the present study was 7% less than early reports.

The maximum amount of all nutrients per hectare was found in the culms followed by the branches, rhizomes and leaves. The amount is highest for K followed by N, Mg, Ca and P, as in *Dendrocalamus hamiltonii* (Toky and Ramakrishnan 1983) and *Bambusa* bambos (Shamughavel 1995); whereas in *Dendrocalamus hamiltoni, Bambusa tulda, Neohouzeua dulloa* and *Bambusa khasiana*, the maximum retention was in the order of K > N > Ca > Mg > P (Rao and Ramakrishnan 1989). The demand for nutrients increases lineally during the period of rapid growth and diminishes at maturity (Pritchett 1975).

This study shows that bamboos follow a strategy of fast uptake and storage of essential elements. Hence, precautions need to be taken during the exploitation of large-scale plantations of *Bambusa vulgaris* Schrad.ex.J.C.Wendl. to avoid nutrient loss and maintain the soil fertility. Nevertheless, it can be recommended as a species for bamboo plantations in social forestry.

CONCLUSION

Bamboo is one of the most important multipurpose species and therefore it is being introduced in a large scale under various programmes of social forestry in India; villagers like to plant it in home gardens, around wells, compounds and in

agricultural fields. Almost every part of the bamboo finds some use. The results of this investigation, indicate the culm production at the fourth year, their length, DBH, and the biomass accumulation etc. Knowledge of the growth characteristics assist in the design of prescripions for the sustainable management of bamboo plantations. Further, by studying the nutrient concentration and retention in the biomass components, one can calculate the nutrient depletion in the field at the time of harvesting of bamboos and recommend appropriate post harvest fertilizer applicaions.

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BIOMASS ACCUMULATION AND NUTRIENT DISTRIBUTION IN *DENDROCALAMUS HAMILTONII*

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ABSTRACT

This paper describes the results from a trial plantation of *Dendrocalamus hamiltonii* grown in the wastelands. The growth, biomass accumulation and nutrient distribution was studied. The number of culms produced per clump varied from 60 to 74. Their maximum height, diameter at breast height and basal area girth are 13m, 3 cm and 5.5 cm respectively. The number of nodes per clump ranged between 39 to 43. The grand total biomass ranges from 30.8 to 36.1 kg DM culm^{-1}. In the above ground biomass, the percent contribution of culms (67%) , branches (26%) and leaves 3%. In below ground rhizome contribution was 5%. The percent distribution of nutrients in different biomass components varied: the ordering of major elemental concentrations was K > N > Mg > Ca > P in branch, culm and rhizome but was N > K > Mg > Ca > P in leaves. The maximum amount of all nutrients occurred in the culms, followed by branches, rhizomes and leaves. In conclusion, this species proved to be an ideal species for the development of wastelands.

KEY WORDS

Biomass accumulation, Nutrient distribution, *Dendrocalamus hamiltonii*.

INTRODUCTION

Bamboo is a fascinating arbores cent grass. For centuries, bamboos have played an important part in the daily life of the people in many tropical countries, particularly in Asia. India has the World's richest resources of bamboo, claiming about 130 species occurring over an area of 10.05 million ha, which is about 12.8% of the total forest area of the country(1). However, bamboo resource in the natural habitat is dwindling, due to over exploitation, gregarious flowering, shifting cultivation and extensive forest fires. A sustained availability can be ensured only by elaborate bamboo cultivation(2). More recently, curiosity about the peculiar plants with their widespread distribution, rapid rate of growth and multipurpose uses has grown. Studies on the effect of container size on seedling growth in a number of species point to the effect of using large containers(3). Performance of bamboo seedlings in nursery are attempted(4,5,6,7). Observations on growth and development of forest bamboos were studied

(8,9). However reports on bamboos in a social forestry is limited (10,11,12). Therefore, an elaborate study was carried out on the performance of bamboo (*Dendrocalamus hamiltonii*) planted in the wastelands at Bharathiar University campus, Coimbatore.

MATERIALS AND METHODS

Study Site:

The study site is located at Bharathiar University Campus, Coimbatore. It is at an altitude of 426.72 MSL, and on latitude 76.93 N. The climate of the area is monsoon. The area has red soils with pH between 7 to 7.8. The electrical conductivity is 0.2 mScm. The maximum soil nitrogen, phosphorus and potassium was 9.8, 7.6 and 115 kg ha respectively. The maximum temperature and rainfall was 31.5°C and 117.5 mm, respectively.

Bamboo Plantation:

Nursery management Practices and Transplanting:

Since bamboo seeds possess a short period of viability (mostly a few days to 1 months)., seedlings from tissue culture were employed for raising bamboo plantation. A nursery area of

10 x 5 m was prepared in the field and filled with a mixture of soil and sand (3:1). Seedlings were pricked out from the polythene bags when about 7 cm in height. About 25-30 seedlings were planted in $1m^2$ of raised nursery bed. Watering was done 2-3 times a day, and care was taken to avoid over saturation. Nursery beds were provided with a thatch to protect the seedlings from direct sunlight.

The seedlings in the nursery were uprooted carefully and transplanted to the field. The seedlings were planted at 6 x 6 m spacing with 250 seedlings /ha. The transplanted seedlings were watered every 2 hrs regularly in the morning and evening. Weeding was done as and as and when required. After 1 year, the plantation was adequately irrigated at 15-days intervals. The plantation was protected against damage by rodents, grazing and browsing animals.

Growth study

From the study area, five clumps were randomly selected and identified with paint marking. The number of culms in these selected clumps were counted. All observation were made for the basal area girth, DBH, height and number of nodes in all culms.

Biomass estimation

In order to estimate the total biomass in relation to organic productivity, 3 clumps were randomly selected from each clump group to a total of 15. For reasons of economy, the rhizome was excavated only from three. After felling, subdivided into leaves, branches, culm

and rhizome. Fresh weight of the components was estimated in the field and sub samples from each component were brought to the laboratory in plastic bags. The sub samples were then oven dried at 103°C at constant weight. From the oven-dry weight of the samples, the total standing biomass of each clump group was calculated by multiplying the total number of the bamboos of each clump with the average dry weight of the sample (2)

Estimation of Nutrients

The nitrogen and phosphorus was estimated using a Technicon Autoanalyzer-II (13) and the nutrients K, Ca and Mg were analyzed using an Atomic Adsorption Spectrophotometer (14).

RESULTS

Growth study

The number of culms produced from 13 year old clump (marked A,B,C,D,E) was counted and are presented in Table 1. It was noticed that the number of culm and their nodes ranges from 60 to 74 and 39 to 43 respectively. The maximum height, diameter at breast height (DBH) and basal area girth one 13m , 3 cm and 5.5 cm respectively.

Biomass production in sample clump

It is seen in Table 2, that the leaf biomass ranges from 0.8 to 0.9 kg DM culm. The branch and culm biomass ranges from 7.9 to 9.3 kg DM culm and 20.9 to 24.1 kg DM culm. The rhizome and grand total biomass varied from 1.4 to 1.7 and 30.8 to 36.1 kg Dm culm respectively.

Percent contribution of biomass components

With regard to contribution of different plant components to total shoot weight (total above ground biomass) the culm contributes maximum in all the clumps. It varied from 66 to 67%. The contribution of leaf, branch and rhizome biomass was 3%, 26% and 5% respectively (Table 3).

Production of biomass on clump basis

The average biomass values of the sample bamboo were multiplied with the number of culms in each clump to calculate the biomass on clump basis (Table 4). It revealed that leaf biomass ranged from 49-6kg / clump, branch biomass from 498 to 629kg/clump, branch biomass from 15-54 kg/clump and rhizome biomass from 089 to 112 kg / clump.

Nutrient concentration:

In Table 5, the average nutrient concentration of the four components of bamboo are given. The highest concentration of different nutrients in the various biomass components was generally observed in leaf, branch, culm and rhizome. The proportions of nutrient elements were in the order to K > N > Mg > Ca > P except for leaf, which the nutrient elements were found in the order of N > K > Mg > Ca > P.

Nutrient Retention

The average annual nutrient retention was obtained by multiplying the productivity of biomass components with their respective nutrient concentration (Table 6). It was observed that on a unit area basis the maximum amount of all nutrients was found in the culm followed by branches, rhizome and leaves. Therefore the maximum drain of all nutrients occurred through culm harvest and among the nutrients the maximum drain occurred in potassium, followed by nitrogen, magnesium, calcium and phosphorus.

DISCUSSION

Growth study

The productivity of bamboo was assessed on the basis of the number of new culms produced annually. At a given site, the production of new culms depended mostly on the degree of congestion, the clump age and the rainfall of the previous year (12). It was noticed that the total number of culms in the selected clumps varied from 60 to 74 per clump. It was observed that the average height of the culm varied from 12 to 13 m. Corresponding basal area girth and dbh varied from 5 to 5.5 cm and 2.5 to 3 cm respectively. The number of nodes in each culm ranged from 39 to 43. Similar results were also observed (12,15,16).

The total standing biomass (kg DM clump) was calculated on the basis of the number of culms in each clump multiplied by the average total above ground biomass of sample culms. The grand total dry matter production 1954 to 2354 kg DM clump at the age of 13. Compared with other biomass measurements, the annual yield of air dry bamboo per hectare of 3-4 years plantation was found to be 6-7 t for *Bambusa vulgaris* (17), 1 t for *Gigantochloa aspera* (17), 297 t for *Bambusa bambos* (2). In *Phyllostachys pubscens* (18,19) the above ground biomass of *Gigantochloa scortechnii* from Malaysia was 71.9 t/ ha in natural stand and 36.67 t/ha in a 3 year old plantation (16). So in the present study the accumulation of biomass was found to be lower. Compared with other fast growing tree species 8.6 t/ha in four years old *Eucalyptus globulus* (20), 47 t/ha in 5 years old *Leucaena leucocephala* (21) and 87 t/ha in 6 years old *Pinus caribaea* (22) the present biomass estimate are found to be 7 to 30% lower.

The nutrient elements in leaf were in the order of N > K > Mg > Ca > P, while in branch, culm and rhizome the order was K > N > Mg > Ca > p. The results are in general agreement with results for *Dendrocalamus hamiltonii* (23), *Bambusa balcooa*, *Dendrocalamus strictus Thyrostachys olivery* (24)) and *Bambusa bambos* (2). In *Bambusa khasiana* the order was K > N > Ca > Mg > P.

Of the cation concentrations that of potassium was the highest. In this context, bamboo plays an important role in the conservation of potassium, because of its capacity for rapid uptake and accumulation. Of the total accumulation potassium alone contributed 43%. Thus in bamboo plantations, the element potassium is predominant over N, Ca, Mg and P, which is analogous to the effect of slash and burn agriculture on plant nutrients in Central Amazonia (25) in a Costa Rican wet forest site (26) in South America, and in *Dendrocalamus strictus* (23) in India. However, the total accumulation of potassium in 13 year old *Dendrocalamus hamiltonii* in the present study was 5% lesser than that reported by previous workers.

On unit area basis, the maximum amount of all nutrients was found in culm followed by branches, rhizomes and leaves. Therefore the drain of its highest K followed by N, Mg, Ca and P as in *Dendrocalamus hamiltonii* (23) and *Bambusa bambos* (2) whereas in *Dendrocalamus hamiltonii*, *Bambusa tulda*, *Neohouzeua dulloa Bambusa chasiana* the maximum retention was in the order of K > N > Ca > Mg > P(27). Since the annual nutrient content is usually followed by biomass expansion (average annual production), it increases linearly during the period of rapid growth and diminishes at maturity(27).

This study shows that bamboos follow a strategy of faster uptake and storage of essential elements. Hence, necessary precautions need to be observed during exploitation of large scale plantations of *Dendrocalamus hamiltonii* to maintain fertility status of the soil. Considering the growth characteristics and biomass accumulation pattern while grown in the wastelands, it can be recommended as one of the species for the wastelands.

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Table1 Characteristics of *Dendrocalanus hamiltonii*

Year	Growth Characters	SAMPLE CLUMPS				
		A	B	C	D	E
13	Total Culm (nos)	60	74	70	65	63
	Average Hight (m)	13	12	12	13	12.5
	Average DBH(Cm)	3	2.5	2.5	2.8	2.5
	Average BA(Cm)	5.5	5.0	5.0	5.0	5.5
	No.of nodes (nos)	43	39	40	41	42

Table 2 Biomass allocation of *Dendrocalams hamiltonii*

Age (years)	Sample Clump	Biomass (Kg/Culm)			Total above ground biomass (Kg)	Rhizome (Kg)	Grand Total biomass (Kg)
		Leaf	Branches	Culm			
13	A	0.950	9.385	24.100	34.435	1.700	36.135
	B	0.800	8.500	21.000	30.300	1.500	31.800
	C	0.750	8.100	20.400	29.250	1.600	30.850
	D	0.750	8.300	21.000	30.050	1.500	31.550
	E	0.800	7.900	20.900	29.600	1.400	31.000

Table 3 Percentage contribution of individual Culm Components

Sample Clump	Leaf biomass %	Branch biomass %	Culm biomass %	Rhizone biomass %
A	3.0	26.0	67.0	4.0
B	2.0	27.0	66.0	5.0
C	3.0	26.0	66.0	5.0
D	2.0	26.0	67.0	5.0
E	3.0	25.0	67.0	5.0

Table 4 Production of biomass on clump basis (Kg)

Sample Clump	Leaf biomass	Branch biomass	Culm biomass	Total above ground biomass	Rhizone biomass	Grand Total biomass
A	57	563	1446	2066	102	2168
B	60	629	1554	2243	111	2354
C	53	567	1428	2048	112	2160
D	49	540	1365	1954	098	2052
E	50	498	1317	1865	089	1954

Table 5 Nutrient concentration in biomass components: (%)

Nutrient	Leaf	Branch	Culm	Rhizome
N	0.75	0.60	0.55	0.40
P	0.08	0.07	0.06	0.05
K	0.60	0.75	0.75	0.65
Ca	0.23	0.20	0.18	0.16
Mg	0.30	0.25	0.22	0.20

Table 6 Nutrient Retained in the biomass components.

Nutrients	Leaf Biomass	Branch biomass	Culm biomass	Total above ground biomass	Rhizome biomass	Grand Total biomass
N	4.0	33.0	80.0	117.0	4.0	121
P	0.48	4.0	9.0	13.4	0.55	14
K	3.0	42.0	107.0	152.0	1.0	159
Ca	1.0	10.0	24.0	35.0	1.0	36.0
Mg	2.0	12.0	28.0	42.0	2.0	4.0

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BIOCHEMICAL CHARACTERISTICS OF PLANTATION BAMBOO *(BAMBUSA BAMBOS)* LEAF WITH REFERENCE TO ORGANIC PRODUCTIVITY

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Bamboo is used in nearly every aspect of daily life in India. However, bamboo diversity in the natural habitat is dwindling, due to over-exploitation, shifting cultivation and extensive forest fires. A sustained availability can be ensured only by elaborate cultivation of bamboo as a crop. A survey of literature reveals that work on the growth and organic productivity of bamboo is very meagre (Sen Gupta 1952, Chacko & Jayaraman 1988, Shanmughavel & Francis 1996), especially on its physiology. Thus the present study was undertaken to evaluate the biochemical characteristics of the leaf of planted *Bambusa bambos* of different age groups with reference to its organic productivity.

A 6-y-old *Bambusa bambos* plantation was selected for the study at Kallipatty, Tamil Nadu, India, located at 12° 28'- 13° 00' E, 76° 59' - 77° 47' N, 540 m a.s.l. The soil is red to brown laterite, sandy loam in texture and has a pH of 7.4 - 7.8. The site has an annual mean temperature of 31 °C and rainfall of 600 mm. The 3-ha area, planted with the bamboo at 6 × 6 m spacing, has been producing rhizomes and healthy culms annually, with growth as shown in Table 2. Fifteen culms from each age group were selected for the biochemical analysis of the fresh leaf for chlorophyll (Arnon 1949), carotenoides (Goodwin 1954), protein (Lowry *et al.* 1951), total soluble carbohydrates (Dubais *et al.* 1956) and starch (McCready *et al.* 1950). For the biomass estimation, 15 culms (3 of which were excavated for their rhizomes) from each age group were randomly selected and felled.

Measurements of the parameters as given in Table 2 were taken from the felled samples, and for the biomass components, from sub-samples brought in plastic bags to the laboratory where they were dried at 103 ± 2 °C to constant weight. The bamboo leaf, which has a Krantz anatomy, typical of a tropical grass, showed contents of chlorophyll, carotenoides, protein, carbohydrates and starch which decreased with age (Table 1). The increasing above-ground biomass, from 1.36 t ha^{-1} for the 1-y-old bamboo to 286.64 t ha^{-1} for the 6-y-old bamboo, was probably due to the higher recruitment of bamboo culms from 1250 t ha^{-1} to 4250 t ha^{-1} in the same periods. The decreasing amounts of food materials in the leaf with age show that this tissue is not important for their storage compared to other parts of the plant, especially the rhizomes, as the plant matures. Although the total chlorophyll content decreased with age, the ratio of chlorophyll a:b generally increased indicating that this ratio influences the photosynthetic efficiency, and hence the productivity of the plant.

The organic productivity (biomass t ha^{-1}) of each plantation increased with age as expected, but at a decreasing rate. This increment is more prominent in the culm than other bamboo components. The grand total biomass increased by 5.4 times from year 1 to year 2, by 4.2 times from year 2 to year 3, by 2.4 times from year 3 to year 4, by 1.5 times from year 4 to year 5, and by 1.3 times from year 5 to year 6. The *Bambusa bambos* in this investigation appears to produce a much larger amount of above-ground biomass than the *B. vulgaris* and *Gigantochloa aspera* reported by Chinte (1965) or the *G. scortechinii* examined by Abd. Razak (1994).

Table 1. Biochemical characteristics of *Bambusa bambos* leaf

Age (y)	Total chlorophyll (µg g^{-1})	Chlorophyll a:b ratio	Carotenoides (µg g^{-1})	Protein (µg g^{-1})	Soluble carbohydrates (µg g^{-1})	Starch (µg g^{-1})
1	551	0.83	64.00	7.53	8.78	588.4
2	544	0.78	58.53	7.23	7.95	537.3
3	500	0.80	53.55	6.89	7.20	495.7
4	449	0.90	50.42	6.19	7.04	481.7
5	398	0.97	49.88	6.07	6.91	475.1
6	366	0.92	48.80	5.97	6.47	469.8

Table 2. Stand characteristics and production of biomass

Age (y)	No. of culms ha^{-1}	Culm diameter (cm)	Culm height (m)	Number of nodes	Biomass t ha^{-1}					
					Leaf	Branch	Culm	Total above ground	Rhizome	Grand total
1	1250	2.3	1.4	7	0.17	0.49	0.70	1.34	0.94	2.29
2	2250	3.3	3.2	16	0.67	1.90	6.80	9.36	3.15	12.51
3	3000	4.3	9.6	37	1.12	17.12	29.25	47.49	4.98	52.47
4	3500	4.8	21.8	86	1.86	27.16	92.75	121.77	6.06	127.83
5	4000	6.3	27.2	98	3.54	33.94	187.22	224.71	9.60	234.31
6	4250	8.3	28.5	103	4.02	39.87	242.73	286.64	11.22	297.86

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ORIGINAL PAPER

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Biomass and nutrient cycling in bamboo (*Bambusa bambos*) plantations of tropical areas

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Abstract Biomass productivity and nutrient cycling in a *Bambusa bambos* plantation aged 4, 5, and 6 years were studied. The dry matter production of above-ground biomass increased progressively with age. Nutrient quantities in bamboo stands were in a range of 1–2 t ha^{-1} for N and K, 0.5–1 t ha^{-1} for Ca and Mg, and 0.1–0.2 t ha^{-1} for P. Nutrient concentrations increased with the age of the plantation. About 10% $year^{-1}$ the nutrients present in the biomass of the bamboo stand are recycled to the soil by litter fall.

Key words Nutrient cycling · Bamboo plantation · *Bambusa bambos* · Biomass harvest · *Eucalyptus* spp. · *Dalbergia sissoo* · *Pinus patula*

Introduction

Bamboo is integral to the culture of Southeast Asia. The diverse bamboo plantations in the natural habitat are dwindling, due to overexploitation, shifting cultivation practices and extensive forest fires. Sustained availability can be ensured only by intensive bamboo cultivation for industrial purposes. One promising species for such cultivation is *Bambusa bambos* (L.) Voss., which is planted for long-fibred pulpwood production. Biocycling of nutrients is an essential process which determines the productivity of these new man-made forest ecosystems. Measurements of the amount and distribution of biomass and nutrients are important in understanding the structure and function of the ecosystem (Grove and Malajczuk 1985). Studies of the chronosequence of even-aged plantations permit the estimation of the rate of stand development and accumulation patterns or organic matter and nutrients (Turner 1983). The assumption underlying such studies is that the selection of a series of stands of different ages represents the various developmental stages of an individual stand (Das and Ramakrishnan 1987).

While there are many studies which can be cited on nutrient cycling in natural forests and plantations from outside the country (Walls and Jorgenson 1975; Turner and Lambert 1983), very few studies have been carried out in India on this topic (George and Varghese 1990a, b; Negi 1984). Moreover, not much work has been carried out in bamboo plantations on various aspects of nutrient cycling such as nutrient retention, nutrient return and nutrient uptake. The present article describes the nutrient cycling in *Bambusa bambos* plantations aged 4, 5 and 6 years grown on the Kallipatty Experimental Farm at Tamil Nadu, India.

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Materials and methods

Study area

The plantation of *Bambusa bambos* studied was located at Kallipatty, which lies between 11°28′ and 12°E latitude and 76°59′ and 77°47′N longitude. Its altitude is 540 m above mean sea level. This area soil was laterite, red to brown in colour and sandy loam in texture. The soil moisture content was determined by drying 10 g fresh soil in a hot-air oven at 150°C for 24 h. The pH was observed on an electric digital pH-meter in a 1:5 (w:v) soil-water suspension. For N, P, K, the samples were air dried and sieved (0.2 mm). Total N was estimated by the indophenol blue method described by Allen (1974). The molybdenum blue method of Jackson (1967) was followed to determine the available soil P. K was extracted from the soil in an ammonium acetate solution (pH=7) and was measured with a digital flame photometer (Systronics-121, India). To obtain the total soil nutrient concentrations per hectare, the percentage nutrient content was divided by 100 and the result multiplied by 2 million. (One hectare contains 2×10^6 kg soil, George and Varghese 1990a). The total soil concentrations of N, P, K, Ca and Mg were 3800, 360, 3600, 1600 and 1800 kg ha^{-1}, respectively. Mean temperature and rainfall for the site are 31°C and 600 mm, respectively.

Biomass estimation

In order to estimate the total biomass in relation to organic productivity, 15 culms were randomly selected from each age group of 45. For

reasons of economy the rhizome was excavated only from three in each age group to a total of nine. After felling, the total height of each culm, diameter at breast height (DBH), basal area, and number of nodes were measured and subdivided into leaves, branches, culm and rhizome. Fresh weight of the components was estimated in the field and subsamples from each component were brought to the laboratory in plastic bags. The subsamples were then oven dried at 103°C±2°C at constant weight. From the oven-dry weight of the samples, the total standing biomass of each age group was calculated by multiplying the total number of the bamboos of different ages with the average dry weight of the sample.

Nutrient analysis

The bamboo was reduced to sawdust by means of an electrical saw. The sawdust was sieved initially with 65 meshes cm^{-2} and later with 200 meshes cm^{-2}. The material retained during the second sieving was called "average wood" and was used for the analysis (the wood used for the analysis was bone dry). Nitrogen and phosphorus were estimated as described by Armstrong et al. (1967) using the Technicon Autoanalyser II (Gedko International, UK). The sample was digested in a Kjeldatherm digestion system KT 408 (Bonn) at 400°C for 3 h. One-gram samples were digested in digestion tubes with both 2.5 g potassium sulphate and 5 ml H_2SO_4. After digestion and cooling, the digested sample was made up to 50 ml with distilled water and used for analysis of N and P. The nutrients K, Ca and Mg were analysed using an atomic adsorption spectrophotometer (Perkin-Elmer 5000, USA) after wet digestion of a 1-g sample with a triple acid mixture (10 ml of conc. HNO_3, 4 ml $HClO_4$ and 1 ml conc. HCl). The digested samples were filtered through Whatman no. 42 filter paper and made up to 100 ml with distilled water and this solution was stored and used for analysis (Issac and Johnson 1975).

Nine litter plots sized 1×5 m were laid down randomly throughout the sample plot. The litter plots were permanently marked by enclosing the area with nylon thread, which lasted throughout the study period. The contents in the litter plots were sampled completely by the end of every month and separated into leaf litter and twig litter. Fresh weight was estimated in the field and subsamples of each component were taken to the laboratory. The subsamples were then oven dried at 80°C to a constant weight. From the sample oven-dry weight the total dry weight of the litter was calculated (Shanmughavel and Francis 1995).

Results and discussion

Biomass and productivity

The production of biomass on a unit area basis is given in Table 1, which shows that the average diameter at breast height (DBH) is a minimum (4.8 cm) at 4 years of age and a maximum (8.3 cm) at 6 years of age. Similarly the minimum height was observed at 4 years of age (21.8 m) and the maximum at 6 years of age (28.5 m). The number of culms was higher in the 6-year-old stand (4250) and lowest in the 4-year-old stand (3500).

The biomass (dry matter) of each plantation increases with age as expected. This increment is more prominent in the culm than the other parts of the bamboo. It was observed that the above-ground biomass increased progressively and amounted to 286 t ha^{-1}. Compared with the measured biomass the annual yield of bamboo ha^{-1} of the 3- to 4-year-old plantation was found to be 7 t ha^{-1} for *Bambusa vulgaris* and 1 t ha^{-1} for *Gigantochloa aspera* (Chinte 1965). The above-ground biomass of the plantation was 85% higher. The above-ground biomass of *Gigantochloa scortechnii* from Malaysia was 72 t ha^{-1} in a natural stand and 36 t ha^{-1} in a 3-year-old plantation (Othman 1992). Compared with the biomass of other fast-growing tree species, 8 t ha^{-1} in 4-year-old *Eucalyptus globulus* (Cromer and Williams 1982), 47 t ha^{-1} in 5-year-old *Leucaena leucocephala* (Pandey et al. 1989) and 87 t ha^{-1} in 6-year-old *Pinus caribaea* (Madgwick et al. 1977), the present biomass estimates are 7–30% higher.

Nutrients retained

The nutrients retained in the average annual production were obtained by multiplying the increase in biomass com-

Table 1 Production of biomass (dry matter) on a unit area basis. Results are the average of three independent observations. Since there was little difference between observations, average values are given

Age (years)	Culm diameter (cm)	Culm height (m)	Basal area (cm^2)	Number of nodes	Number of culms	Biomass (t ha^{-1})			Total above-ground biomass (t ha^{-1})
						Leaf	Branches	Culm	
4	4.8	21.8	6.1	86	3500	1.9	27.2	92.8	122
5	6.3	27.2	8.3	98	4000	3.5	33.9	187.2	225
6	8.3	28.5	10.1	103	4250	4.0	39.9	242.7	287

Table 2 Nutrient content in the average annual biomass production. Results are the average of three independent observations. Since there was little difference between observations, average values are given

Components	4 years					5 years					6 years				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
	(kg ha^{-1} $year^{-1}$)														
Culm	686	65	733	334	399	1460	150	1535	730	824	1990	194	2160	995	1117
Branches	215	22	228	79	109	282	27	302	129	156	355	36	399	172	191
Leaves	18	2	17	7	9	34	4	34	16	18	42	4	40	21	22
Rhizomes	43	4	44	21	21	70	7	76	35	37	86	8	94	44	48

Table 3 Nutrient return (kg ha^{-1} $year^{-1}$) through litter fall. Results are the average of three independent observations. Since there was little difference between observations, averages given

Nutrients	4 years			5 years			6 years		
	Leaf	Twig	Total	Leaf	Twig	Total	Leaf	Twig	Total
Litter production (t ha^{-1})	9.2	6.2	15.4	10.3	7.3	17.6	11.8	84.7	20.3
N	84	36	120	96	45	141	115	69	184
P	7	3	10	9	4	13	9	7	16
K	58	43	101	67	54	121	110	73	183
Ca	41	19	60	48	24	72	57	34	91
Mg	43	23	66	50	29	79	60	36	96

ponents by their respective nutrient concentration (Table 2). The nutrient contents of the standing crop differ substantially between various forest types according to the degree of uptake and crop biomass, which in turn depend on tree age and site quality even within the same species. The increase in nutrient contents of the standing crop with stand age observed in this study, has a direct relationship to the total biomass of a forest stand (Roddin and Bazilevich 1967). As such, the nutrients accumulated in various tree components vary considerably. It was observed that, on a unit area basis, the maximum amount of all nutrients was found in the culm followed by the branches, rhizomes and leaves. Therefore the maximum drain of K occurs followed by N, Mg, Ca and P as in *Dendrocalamus hamiltonii* (Toky and Ramakrishnan 1982), whereas in *Bambusa tulda, Neohouzeau dulloa* and *Bambusa khasiana* the maximum retention is in the order K>N>Ca>Mg>P (Rao and Ramakrishnan 1989). Since the annual nutrient content is usually followed by biomass growth (average annual production), it increases linearly during the period of rapid growth and diminishes at maturity (Pritchett 1979). The same holds true for *Bambusa bambos* plantations, where the average annual production is at a maximum at 6 years of age and similarly the annual accumulation of nutrients also attains a peak value. These results are in general agreement with earlier observations (Walls and Jorgenson 1975; Negi and Sharma 1984).

The nutrient retention in *Banbusa bambos* plantations was not within the values obtained in other plantations, e.g. *Pinus radiata* (Madwick et al. 1977), *P. banksiana* (Foster and Morrison 1970), *P. Kesiya* (Das and Ramakrishnan 1987), *Eucalyptus hybrid* (Negi 1974; George 1977), *E. grandis* (Turner and Lambert 1983), and *E. marginata* (Hingston et al. 1981), but was found to be 14–85% higher. This may be due to the higher number of culms in the present study.

Nutrient return

Estimation of litter production and nutrients return was carried out and the results are presented in Table 3. It was observed that of the total litter (15 t ha^{-1}) in the 4th year 60% was contributed by the leaf and 40% by the twigs. However, during the 5th (18 t ha^{-1}) and 6th years (20 t ha^{-1}), 58% was contributed by the leaf and 42% by the twigs. With regard to nutrient return, nearly 60–70% was returned through the leaf litter and the rest by the twigs. Similar results were observed by George and Varghese (1990b).

Nutrient uptake and cycling

On the basis of the above results, nutrient cycling in the plantation on an annual basis was calculated. Of the total uptake of nitrogen, 89% was retained while 11% was returned to the soil. Similarly, 90% of total phosphorus was retained and 10% returned. With regards to K, Ca and Mg, 91%, 89% and 89% was retained and 9%, 11% and 11% was returned, respectively in the 4th year. In the 5th and 6th years, of the total uptake of nitrogen, phosphorus, calcium and magnesium, 93% was retained and only 7% was returned. Thus it is seen that *Bambusa bambos* retains more nutrients than it returns. The results of the present study therefore emphasize the importance of the application of external fertilizers after the harvest of biomass components.

The concentration of nutrients in the aerialshoots and rhizome increased with age (Tables 4–7). The nutrient ele-

Table 4 Nutrient concentration in the branch. Results are averages of three independent experiments

Total nutrients	Year					
	1 (g kg^{-1})	2 (g kg^{-1})	3 (g kg^{-1})	4 (g kg^{-1})	5 (g kg^{-1})	6 (g kg^{-1})
N	6.5	6.7	7.0	7.9	8.3	8.9
P	0.7	0.7	0.8	0.8	0.8	0.9
K	6.7	7.3	7.8	8.4	8.9	10
Ca	2.0	2.3	2.9	3.1	3.8	4.3
Mg	3.0	3.2	3.8	4.0	4.6	4.8

Table 5 Nutrient concentration in the culm. Results are averages of three independent experiments

Total nutrients	Year					
	1 (g kg^{-1})	2 (g kg^{-1})	3 (g kg^{-1})	4 (g kg^{-1})	5 (g kg^{-1})	6 (g kg^{-1})
N	6.0	6.4	6.7	7.4	7.8	8.2
P	0.6	0.6	0.7	0.8	0.8	0.8
K	6.4	6.9	7.4	7.9	8.2	8.9
Ca	1.8	2.3	3.0	3.6	3.9	4.1
Mg	2.9	3.3	4.1	4.3	4.4	4.6

Table 6 Nutrient concentration in the leaf. Results are averages of three independent experiments

Total nutrients	Year					
	1 (g kg^{-1})	2 (g kg^{-1})	3 (g kg^{-1})	4 (g kg^{-1})	5 (g kg^{-1})	6 (g kg^{-1})
N	7.9	8.8	9.0	9.3	9.7	10.5
P	0.8	0.8	0.9	0.9	10	10
K	7.6	8.2	8.7	9.0	9 5	10
Ca	2.3	2.9	3.3	3.8	4.4	5.1
Mg	3.4	3.7	4.3	4.9	5.2	5.4

Table 7 Nutrient concentration in the rhizomes. Results are averages of three independent experiments

Total nutrients	Year					
	1 (g kg^{-1})	2 (g kg^{-1})	3 (g kg^{-1})	4 (g kg^{-1})	5 (g kg^{-1})	6 (g kg^{-1})
N	5.7	6.0	6.3	6.9	7.3	7.7
P	0.5	0.5	0.6	0.6	0.7	0.7
K	6.0	6.4	6.9	7.3	7.9	8.4
Ca	1.6	2.0	2.9	3.4	3.6	3.9
Mg	2.5	2.7	3.1	3.5	3.9	4.3

ment in the leaf was in the order N>K>Mg>Ca>P, while in the branch, culm and rhizome it was K>N>Mg>Ca>P.

This study has compared the nutrient uptake which is retained and returned in various plantation ecosystems. It is seen that, unlike in *Pinus patula* (Bhartari 1986), *Dalbergia sissoo* (Sharma et al. 1988), *Eucalyptus grandis* (Westmann 1978; Turner and Lambert 1983), and *E. globulus* (George and Varghese 1990a), in *Bambusa bambos* nutrients are utilized more than returned.

The quantities of Mg present in the various plant parts of bamboo are at least as high as the quantities of Ca. However, in most plant species the Ca quantities are higher than those of Mg. Similar results were reported by Toky and Ramakrishnan (1982) in the bamboo *Dendrocalamus hamiltonii*.

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RESEARCH NOTES

Distribution of nutrients in an age-series of *Bambusa bambos* plantation

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SUMMARY

The distribution of nutrients in *Bambusa bambos* plantations of different ages growing in Kallipatty, Tamilnadu has been studied. The percentage distribution of nutrients in different biomass components varied: the ordering of major elements concentrations was K>N>Mg>Ca>P in branch, culm and rhizome but was N>K>Mg>Ca>P in leaves. The maximum amount of all nutrients per ha occurred in the culms, followed by branches, rhizomes and leaves. Harvesting the above-ground biomass of 286 tonnes per ha at 6 years would result in the removal of 2377, 234, 2599, 1188 and 1330 kg per ha of N, P, K, Ca and Mg respectively. Culm forms 85% of the total biomass and accounts for 58-69% of all nutrients in the plants.

Keywords: age-class, *Bambusa bambos*, nutrient distribution.

INTRODUCTION

For a proper understanding and management of the forest ecosystem, particularly man-made forests, the total biological approach requires knowledge of nutrient flows. Substantial information is available on nutrient content and cycling in temperate, tropical and subtropical ecosystems of the world (see, for example, Field 1983, George 1977, Gessel and Turner 1974, Prasad *et al.* 1984, Rodin and Bazilevich 1967) but little is known about the species *Bambusa bambos*. This is a densely tufted bamboo with curving branches which develop from all nodes from the base upwards. The lower branches are spreading and bear recurved spines. Branches are periodically removed for ease of access. *B. bambos* is the fastest growing species, attaining harvestable maturity within 3 years. It is a favoured species in afforestation programmes.

The objective of the present study was to determine the distribution of nutrient content in *Bambusa bambos* plantation of different ages.

MATERIAL AND METHODS

Study Site

The study area of plantation *Bambusa bambos* is 6 years old and is located at Kallipatty, Tamilnadu between 11°28' and 12° E of latitude and 76°59' and 77°47' N longitude. The 3 ha site lies 540 m above sea level. The mean temperature is 31°C and mean annual rainfall about 600 m. Soils from 9" plough depth were taken for nutrient analysis. Soil pH was between 7.4 and 7.8. The maximum soil nitrogen, phosphorus, potassium, calcium and magnesium were 3800, 360, 3600, 1600 and 1800 kg per ha respectively.

Seedlings raised by tissue culture had been planted at 6 m by 6 m spacing. The plantations was subsequently irrigated at intervals of 15 days, care being taken to avoid waterlogging. Plants were protected from damage by mammals.

Biomass estimation

In order to estimate the total biomass in relation to organic productivity fifteen culms were selected randomly from each age group of the plantation. The selected culms were felled to provide a total of ninety over the 6 ages of plants studied. A total of 18 rhizomes, 3 from each year plantation, were excavated for determination of underground biomass by making a trench around the culm. After felling, the total height of each culm, DBH, basal diameter and number of nodes were measured and sub-divided into four main components, leaves, branches, culm (bole) and rhizome. The components were brought to the laboratory in plastic bags and fresh weights were assessed. The subsamples were then oven dried at 103 ± 2°C a to a constant weight.

Total standing biomass in tonnes per hectare dry matter of each age group was calculated by multiplying the total number of the bamboos by the average dry weight of the

sample. The mean annual biomass production (total biomass divided by age) and periodic production (the difference between biomass measurement of two stands in a sequence divided by the age interval) and net primary productivity, were estimated.

Estimation of nutrient elements

Nitrogen and phosphorus was estimated as described by Armstrong *et al.* (1967) using Technicon Autoanalyser-II (Gedko International Ltd., U.K.). The nutrients potassium, calcium and magnesium were analysed as described by Issac and Johnson (1975) using an atomic absorption spectrophotometer (Perkin Elmer 5000 U.S.A.).

RESULTS AND DISCUSSION

Stand growth and biomass

The details of stand growth, density and biomass are given in Table 1. Average DBH rose from 2.3 cm at 1 year to 8.3 cm at 6 years, while mean height increased from 1.4 m to 28.5 m at 6 years. The culm density was highest in the six year old stand (4250 culms/ha) and lowest in the first year (1250 culms/ha). An increasing proportion of total biomass occurs in the culm with age.

Nutrient concentration

The concentration of nutrients in the aerial shoots and rhizome increased with age. The nutrient elements in leaf was in order of N>K>Mg>Ca>P, while in branch, culm, rhizome was K>N>Mg>Ca>P. These are in general agreement with findings for *Dendrocalamus hamiltonii* (Toky and Ramakrishnan 1983) and *Bambusa balcooa, Dendrocalamus strictus and Thyrostachy olivery* (Tewari *et al.* 1994). In *Bambusa khasiana* the order was K>N>Ca>Mg >P (Rao and Ramakrishnan 1989).

Among the cations the concentration of potassium was highest. Bamboo plays an important role in the conservation of potassium because of its rapid uptake and accumulation. Thus in this bamboo plantation, potassium, as the predominant element over N, Ca, Mg and P, is found to be similar to that occurring in bamboo forest following slash and burn agriculture in central Amazonia (Brinkman and Nascimento 1973), a Costa Rican wet forest site (Ewel *et al.* 1981) and *Dendrocalamus strictus* (Toky and Ramakrishnan 1983) in India. However, the total accumulation of potassium in 6 year old *Bambusa bambos* of the present study was 5 to 10 per cent higher than the levels reported by previous workers.

Nitrogen in leaves was found to be proportionately higher than other tissues in the present study. Higher allocation of N to the leaf component may be related to photosynthetic efficiency, since leaf nitrogen is positively related to photosynthetic rate (Field 1983, Rao and Ramakrishnan 1989). In *Dendrocalamus hamiltonii* (Toky and Ramakrishnan 1983) on the other hand, K replaced nitrogen in the leaf as the major nutrient.

Total nutrients per hectare

The nutrient content of the standing crop differs substantially in various forest types according to the degree of uptake and crop biomass, which in turn are dependent on tree age and site quality (Rodin and Bazilevich 1967). Nutrients retained per ha at age 6 years of the crop under investigation are shown in Table 2. The ordering in the culm of K followed by N, Mg, Ca and P is as in *Dendrocalmus hamiltonii* (Toky and Ramakrishnan 1983), whereas in *Dendrocalamus hamiltonii, Bambusa tulda, Neohouzeva dulloa* and *Bambusa khasiana* the ordering was K>N> Ca>Mg>P (Rao and Ramakrishnan 1989).

TABLE 1 *Production of biomass per unit area*

Age (years)	Culm DBH (cm)	Culm height (m)	Basal diameter (cm)	Number of culms	Mean number of nodes	Biomass (tonnes per hectare)					
						Leaf	Branches	Culm	Total above ground	Rhizome	Grand total
1	2.3	1.4	3.1	1,250	7	0.166	0.493	0.698	1,356	0.938	2,294
2	3.3	3.2	4.0	2,250	16	0.668	1.897	6.795	9,360	3.150	12,510
3	4.3	9.6	5.0	3,000	37	1.122	17.115	29.250	47,487	4.980	52,467
4	4.8	21.8	6.1	3,500	86	1.862	27.160	92.750	121,772	6.055	127,827
5	6.3	27.2	8.3	4,000	98	3.544	33.940	187.224	224,708	9.600	234,308
6	8.3	28.5	10.1	4,250	103	4.021	39.886	242.730	286,637	11.220	297,857

TABLE 2 *Nutrient retained in the average annual production to age 6 in* Bambusa bambos[1]

Components	Nutrients, Kg, ha-1 yr-1				
	N	P	K	Ca	Mg
Leaf	42	4	40	21	22
Branches	355	36	399	172	191
Culm	1990	194	2160	995	1117
Total above ground	2387	234	2599	1188	1330
Rhizome	86	8	94	44	48

[1] Detailed results for each age of bamboo are obtainable from the senior author (P.S.)

In harvesting these plantations all biomass components apart from rhizomes are removed. In view of the high nutrient contents found, it is clear that fertilization is likely to be necessary in order to maintain the fertility of the soil.

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ORIGINAL PAPER

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Balance and turnover of nutrients in a bamboo plantation (*Bambusa bambos*) of different ages

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Abstract The accumulation of nutrients by a bamboo plantation and their rate of uptake and release through litter fall was determined. The nutrients in the above-ground living biomass increased linearly with plant age. The balance of nutrients showed an increase in loss by litter fall, and annual nutrient accumulation and enrichment ratio were enhanced with age. Annual percentage turnover showed no consistent trend. Enrichment ratios were in the order of K>N>Mg>Ca>P. In conclusion, precautions are necessary during the exploitation of bamboo plantations on a large scale in order to prevent nutrient depletion of the soil.

Key words Nutrient balance · Bamboo plantation · Nutrient depletion · *Bambusa bambos* · Annual turnover · Bamboo biomass

Introduction

Bamboos are found in large forest areas growing throughout Asia and the Pacific area. Although a major part of the requirements for bamboo is presently being met from natural stands, the increasing demand for housing and construction can be provided for in the future only from extended plantations on marginal soils (Coxi- and Ultisols). Extensive plantations of bamboos, mostly *Bambusa bambos*, have recently been grown in several regions of India to meet the increasing demand for long-fibre pulping material (Tewari et al. 1994). In bamboo plantations, a knowledge of the cycling of nutrients is essential to maintain or even increase the productivity status of the nutritionally poor soils concerned. There is little information about the role of bamboos in nutrient depletion and recycling during secondary succession following slash and burn agriculture in northeast India (Toky and Ramakrishnan 1982; Rao and Ramakrishnan 1989). Little is known about nutrient cycling and annual turnover of the major nutrients (Toky and Ramakrishnan 1982). In fact, there have been virtually no basic studies carried out on nutrient cycling in bamboo plantations. This study aimed to determine the main patterns of nutrient accumulation in the different biomass components, their return through litter fall, and the percentage annual turnover of N, P, K, Ca and Mg within a plantation of different ages in south India.

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Economic botany

Bamboo, which are giant, woody, tree-like grasses, have a long history as an exceptionally versatile and widely used resource. Over 75 genera and 1250 species are reported to occur throughout the world, Bamboo is known variously as the "poor man's timber", the cradle to coffin plant and "green gold". Bamboo has and still does provide the materials needed for existence. It is also an eminently renewable resource. Under suitable conditions this crop displays prodigious rates of growth. Some species can produce culms 40 m high and 30 cm in diameter in only 4 months. The total lengths of culms produced by a giant bamboo clump over its lifetime can well exceed 15 km. It has two kinds of flowering behaviour: firstly a sporadic and irregular flowering and, secondly, periodical gregarious flowering. The gregarious flowering is followed by the death of the clump and varies from 20 to 75 years depending upon the locality, management practices and biotic interferences (Shanmughavel 1995).

A complete bamboo plant consists of three morphologic structures, the leafy aerial part (the culm) and two underground parts (the rhizome and the roots). For successful growth all these structures must develop. Failure in the development of any of these phases leads to complete failure. Most bamboo species of commercial importance form clumps (a cluster of culms). The new seedling (the seedlings resembles a blade of grass) produces a rhizome, which develop new rhizomes that produce culms. The

number of new rhizomes may vary from one to many. Depending upon the production of rhizomes, bamboos are classified into three types: (1) monopodial (the rhizome having one bud at each node which develops monopodially every year). (2) sympodial – the apex of the rhizome having nodes but no buds does as the monopodial type, and protruding out of the ground and growing into a culm. In the following year, the bud on the basal part of the culm develops into a short rhizome, which protrudes out of the ground to make a secondary culm, thus forming a clump. (3) The third type is known as intermediate (intermediate between monopodial and sympodial).

Over exploitation associated with a growing human population, destruction of tropical forests and new demands on this resource for industrial uses, especially by the pulp and paper industry, has resulted in the wide-scale decimation of bamboo stocks. From vast forests of bamboo in south and southeast Asia at the beginning of this century, we are left with the current situation of acute scarcity. Many countries have been forced to severely restrict and in some cases even ban outright the harvesting and exporting of bamboos. The present crisis of sustaining the availability of bamboo can be ensured only by the raising of bamboo plantations.

Nursery management practices and transplanting

Since bamboo seeds possess a short period of viability (a few days to 1 month), seedlings from tissue culture were employed for raising bamboo plantations. A nursery area of 10×5 m was prepared in the field and filled with a mixture of soil and sand (3:1). The seedlings were pricked out from the polythene bags when about 7 cm in height. About 25–30 seedlings were planted in 1 m^2 of raised nursery bed. Watering was done 2–3 times a day, and care taken to avoid oversaturation. Nursery beds were provided with a thatch to protect the seedlings from direct sunlight.

The seedlings in the nursery were uprooted carefully and transplanted to the field. The seedlings were planted at 6×6 m spacing with 250 seedlings ha^{-1}. The transplanted seedlings were watered every 2 h regularly in the morning and evening. Weeding was done as and when required. After 1 year, the plantation was adequately irrigated at 15-day intervals. Care was taken to avoid waterlogging. The plantation was protected against damage by rodents, and grazing and browsing animals.

Annual recruitment of culms

The productivity of bamboo is assessed by the number of new culms produced annually. At a given site the production of new culms mostly depends on the culms of the previous year, the degree of congestion and the clump age. In the trial plantation at Kallipatty, Tamil Nadu, culm emergence took place the year following planting. Seedlings of *Bambusa bambos* produced only five culms per clump in the 1st year after planting. The average number of culms gradually increased in the subsequent years to 8, 12, 14, 16 and 17 $clump^{-1}$. Culms emerging in the 1st year were short (1.4 m) in length and small in diameter (2.3 cm at breast height). Culms produced in subsequent years were distincty taller and thicker (Shanmughavel 1995).

Materials and methods

Study area

The 6-year plantation of *Bambusa bambos* studied was located at Kallipatty, Tamil Nadu, which lies between 11°28′ and 12°E latitude and 76°, 59′ and 77°47° N longitude. Its altitude is 540 m above mean sea level. This area soil was laterite, red to brown in colour and sandy loam in texture (USDA 1975). The soil moisture content was determined by drying 10 g fresh soil in a hot-air oven at 150°C for 24 h. The pH (7.4–7.8) was observed on an electric digital pH-meter in a 1.5 (w:v) soil-water suspension. For N, P and K, the samples were air dried and sieved (0.2 mm). Total N was estimated by the indophenol blue method described by Allen (1974). The molybdenum blue method of Jackson (1967) was followed to determine the available soil P. Potassium was extracted from the soil in an ammonium acetate solution (pH=7) and was measured with a digital flame photometer (Systronics-121, India). To obtain the total soil nutrient concentrations per hectare, the percentage nutrient content was divided by 100 and the result multiplied by 2 million. One hectare usually contains ca. 2×10^6 kg soil (George and Varghese 1990a). The total soil concentrations of N, P, K, Ca and Mg were 3800, 360, 3600, 1600 and 1800 kg ha^{-1}, respectively. Mean temperature and rainfall for the site are 31°C and 600 mm, respectively.

Biomass estimation

In order to estimate the total biomass in relation to organic productivity, 15 culms were randomly selected from each age group of 90. For reasons of economy, the rhizome was excavated from only 3 in each age group to a total of 18. After felling, the total height of each culm, diameter at breast height (DBH), basal area and number of nodes were measured and subdivided into leaves, branches, culm and rhizome. Fresh weight of the components was estimated in the field of subsamples from each component were brought to the laboratory in plastic bags. The subsamples were then oven dried at 103±2°C at constant weight. From the oven-dry weight of the samples, the total standing biomass of each age group was calculated by multiplying the total number of the bamboos of different ages with the average dry weight of the sample.

Litter estimation

Nine litter plots sized 1×5 m were laid down randomly throughout the sample plot. The litter plots were permanently marked by enclosing the area with nylon thread, which lasted throughout the study period. The contents in the litter plots were sampled completely by the end of every month and separated into leaf litter and twig litter. Fresh weight was estimated in the field and subsamples of each component were taken to the laboratory. The subsamples were then oven dried at 80°C to a constant weight. From the sample oven-dry weight the total dry weight of the litter was calculated (Shanmughavel and Francis 1995).

Nutrient analysis

The bamboo was reduced to sawdust by means of an electrical saw. The sawdust was sieved initially with 65 meshes cm^{-2} and later with 200 meshes cm^{-2}. The material retained during the second sieving was called "average wood" and was used for the analysis (the wood

Table 1 Nutrient concentration in the leaves

Nutrients (mg g^{-1})	Age (years)					
	1	2	3	4	5	6
N	7.9	8.8	9.0	9.3	9.7	10.5
P	0.8	0.8	0.9	0.9	1.0	1.0
K	7.6	8.2	8.7	9.0	9.5	10.0
Ca	2.3	2.9	3.3	3.8	4.4	5.1
Mg	3.4	3.7	4.3	4.9	5.2	5.4

Results are the average of three independent observations. Since there was little difference between observations, average values are given

Table 2 Nutrient concentration in the branches

Nutrients (mg g^{-1})	Age (years)					
	1	2	3	4	5	6
N	6.5	6.7	7.0	7.9	8.2	8.9
P	0.7	0.7	0.8	0.8	0.8	0.9
K	6.7	7.3	7.8	8.4	8.9	10.0
Ca	2.0	2.3	2.9	3.1	3.8	4.3
Mg	3.0	3.2	3.8	4.0	4.6	4.8

Results are the average of three independent observations. Since there was little difference between observations, average values are given

Table 3 Nutrient concentration in the culms

Nutrients (mg g^{-1})	Age (years)					
	1	2	3	4	5	6
N	6.0	6.4	6.7	7.4	7.8	8.2
P	0.6	0.6	0.7	0.7	0.8	0.8
K	6.4	6.9	7.4	7.9	8.2	8.9
Ca	1.8	2.3	3.0	3.6	3.9	4.1
Mg	2.9	3.3	4.1	4.3	4.4	4.6

Results are the average of independent observations. Since there was little difference between observations, average values are given

Table 4 Nutrient concentration in the rhizomes

Nutrients (mg g^{-1})	Age (years)					
	1	2	3	4	5	6
N	5.7	6.0	6.3	6.9	7.3	7.7
P	0.5	0.5	0.6	0.6	0.7	0.7
K	6.0	6.4	6.9	7.3	7.9	8.4
Ca	1.6	2.0	2.9	3.4	3.6	3.9
Mg	2.5	2.7	3.1	3.5	3.9	4.3

Results are the average of three independent observations. Since there was little difference between observations, average values are given

used for the analysis was bone dry). Nitrogen and phosphorus were estimated as described by Armstrong et al. (1976) using the Technicon Autoanalyser II (Gedko Intermation, UK). The sample was digested in a Kjeldatherm digestion system KT 408 (Bonn) at 400°C for 3 h. One-gram samples were digested in digestion tubes with both

Table 5 Distribution (% dry matter) of nutrients in the above-ground biomass of bamboo at different ages

Years	Nutrients (% dry matter)	Leaves	Branch	Culm
1	N	36	37	34
	P	4	4	4
	K	35	37	34
	Ca	10	11	10
	Mg	15	11	16
2	N	37	34	33
	P	3	3	3
	K	35	37	35
	Ca	12	10	12
	Mg	13	16	17
3	N	34	32	30
	P	3	4	3
	K	33	36	34
	Ca	13	10	14
	Mg	17	18	19
4	N	34	33	31
	P	3	3	3
	K	33	35	33
	Ca	13	12	15
	Mg	17	17	18
5	N	33	31	31
	P	3	3	3
	K	32	34	33
	Ca	15	14	15
	Mg	17	18	18
6	N	33	31	31
	P	3	3	3
	K	31	35	33
	Ca	16	15	16
	Mg	17	16	17

2.5 g potassium sulphate and 5 ml H_2SO_4. After digestion and cooling, the digested sample was made up to 50 ml with distilled water and used for analysis of N and P. The nutrients K, Ca and Mg were analysed using an atomic adsorption spectrophotometer (Perkin-Elmer 5000, USA) after wet digestion of a 1-g sample with a triple acid mixture (10 ml conc. HNO_3, 4 ml $HClO_4$ and 1 ml conc. HCl). The digested samples were filtered through Whatman No. 42 filter paper and made up to 100 ml with distilled water and this solution was stored and used for analysis (Issac and Johnson 1975). All analysis was performed on the average of three replicates.

Results

Nutrient concentration in different components

In Tables 1–4 the average nutrient concentrations of the four components of bamboo for all six age groups are given. The highest conncentration of different nutrients in the various biomass components was generally observed in leaf, branch, culm and rhizome. The proportions of nutrient elements were in the order of K>N>Mg>Ca>P except for leaf, which the nutrient elements were found in the order of N>K>Mg>Ca>P.

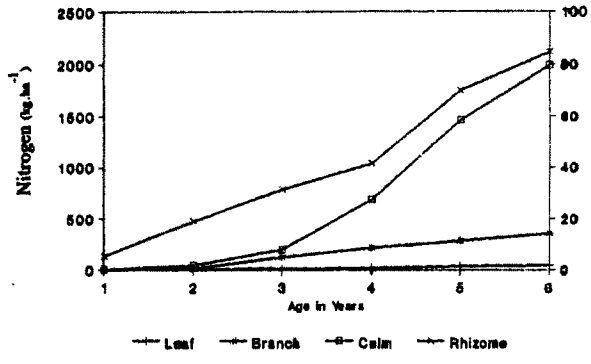

Fig. 1 Each value expressed is the mean of three independent experiments. The nitrogen retained in leaves varied from 1.31 to 42.20 kg ha^{-1}, in branches from 3.20 to 3.55 kg ha^{-1}, in culm from 4.18 to 1990 kg ha^{-1} and in rhizomes from 5.30 to 86 kg ha^{-1}

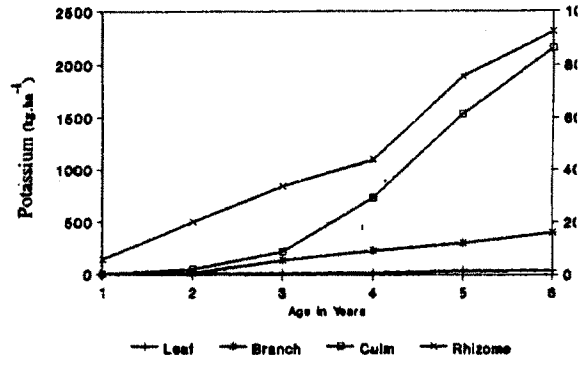

Fig. 3 Each value expressed is the mean of three independent expe
ments. The potassium retained in leaves varied from 1.26
40 kg ha^{-1}, in branches from 3.30 to 399 kg ha^{-1}, in culm from 4.
to 2160 kg ha^{-1} and in rhizomes from 5.62 to 94 kg ha^{-1}

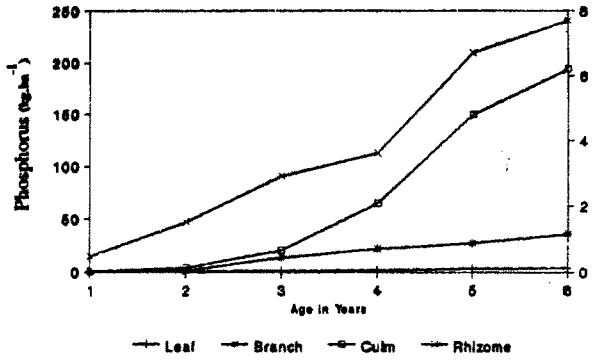

Fig. 2 Each value expressed is the mean of three independent experiments. The phosphorus retained in leaves varied from 0.13 to 4.10 kg ha^{-1}, in branches from 0.34 to 36.00 kg ha^{-1}, in culm from 0.41 to 194 kg ha^{-1} and in rhizomes from 0.46 to 8 kg ha^{-1}

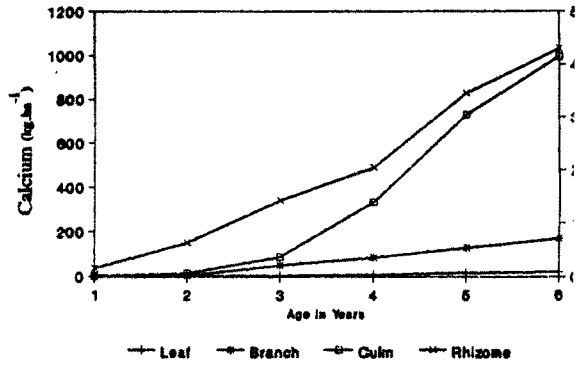

Fig. 4 Each value expressed is the mean of three independent expe
ments. The calcium retained in leaves varied from 0.38 to 21 kg ha
in branches from 3.30 to 399 kg ha^{-1}, in culm from 1.25
995 kg ha^{-1} and in rhizomes from 1.50 to 44 kg ha^{-1}

Distribution of nutrient elements in different components

In Table 5, the distribution of elements in the leaf, branch, culm and rhizome are shown. The leaf contained 33–36% of N, 3–4% of P, 31–35% of K, 10–16% Ca and 15–17% of Mg. The branches contained 31–37% N, 3–4% P, 35–37% K, 10–15% Ca and 11–18% Mg. The higher concentrations were observed in the culm, which contained 30–34% N, 3–4% P, 33–36% K, 10–15% Ca and 17–19% Mg in the aerial shoots of 1- to 6-year-aged plantation *Bambusa bambos.*

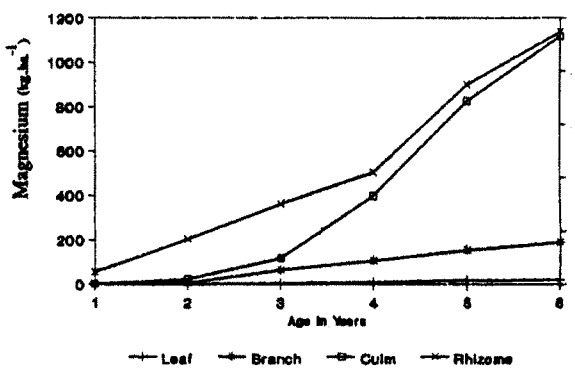

Fig. 5 Each value expressed is the mean of three experiments. T
magnesium retained in leaves varied from 0.56 to 22 kg ha^{-1},
branches from 1 to 191 kg ha^{-1}, in culm from 2 to 1117 kg ha^{-1} a
in rhizomes from 2 to 48 kg ha^{-1}

Nutrient retention

The average annual nutrient retention was obtained by multiplying the productivity of biomass components with their respective nutrient concentration (Figs. 1–5). It was observed than on a unit area basis the maximum amount of all nutrients was found in culm followed by branches, rhizome and leaves. Therefore the maximum drain of all nutrients occurred through culm harvest and among the

Table 6 Balance and turnover of nutrient elements in a bamboo plantation of different ages

Balance and turnover	Age (years)					
	1	2	3	4	5	6
Above-ground biomass (t ha^{-1})	1.3	9.3	47.4	122.0	225.0	287.0
N						
Release through litter (kg ha^{-1})	2.3	36.0	73.0	150.0	170.0	196.0
Annual turnover (%)	16.4	44.2	20.4	15.5	9.2	8.0
Annual nutrient accumulation (kg ha^{-1})	8.6	62.3	326.0	919.0	1776.3	2387.2
Enrichment ratio	5.0	7.0	8.0	8.1	23.3	34.0
P						
Release through litter (kg ha^{-1})	0.14	2.2	5.3	10.0	14.0	16.0
Annual turnover (%)	10.4	31.2	14.0	12.0	7.3	6.6
Annual nutrient accumulation (kg ha^{-1})	0.8	5.5	35.0	88.0	180.5	234.0
Enrichment ratio	0.4	0.5	0.8	0.8	2.3	3.3
K						
Release through litter (kg ha^{-1})	2.2	35.3	72.2	146.3	165.3	188.7
Annual turnover (%)	15.0	52.0	18.3	14.3	8.4	7.0
Annual nutrient accumulation (kg ha^{-1})	9.0	66.3	359.0	978.0	1870.0	2599.0
Enrichment ratio	5.3	5.0	9.4	8.4	24.4	35.3
Ca						
Release through litter (kg ha^{-1})	0.96	15.5	33.4	69.3	84.4	97.4
Annual turnover (%)	23.3	56.2	23.3	15.0	9.0	8.0
Annual nutrient accumulation (kg ha^{-1})	2.6	21.4	130.0	420.0	875.0	1188.0
Enrichment ratio	1.4	2.3	3.1	3.4	11.4	16.4
Mg						
Release through litter (kg ha^{-1})	1.0	17.1	35.0	73.0	88.0	103.5
Annual turnover (%)	19.4	43.3	17.0	13.0	8.5	7.5
Annual nutrient accumulation (kg ha^{-1})	3.5	30.4	189.0	517.0	998.0	1330.0
Enrichment ratio	2.0	3.3	4.4	4.5	13.0	18.3

nutrients the maximum drain occurred in potassium, followed by nitrogen, magnesium, calcium and phosphorus.

Inventory of nutrient elements

The balance and turnover of elements (Table 6) showed that the nutrient release through litter fall, annual nutrient accumulation and enrichment ratio was found to increase with age. However annual percentage turnover did not show a regular trend; increased up to the 2nd year, but was found to be decrease thereafter.

Discussion

The concentration of nutrients in the aerial shoots and rhizome increased with age. The nutrients elements in leaf were in the order of N>K>Mg>Ca>P, while in branch, culm and rhizome the order was K>N>Mg>G>P. These are in general agreement with results for *Dendrocalamus hamiltonii* (Toky and Ramakrishnan 1983) and *Bambusa balcooa, Dendrocalamus strictus* and *Thyrostachys Olivery* (Tewari et al. 1994). In *Bambusa Khasiana* the order was K>N>Ca>Mg>P (Rao and Ramakrishnan 1989).

Of the cation concentrations, that of potassium was the highest. In this context, bamboo plays an important role in the conservation of potassium because of its capacity for rapid uptake and accumulation. Of the total accumulation of nutrients over 6 years, potassium alone contributed about 51%. The weight of elements increased linearly with biomass (Toky and Ramakrishnan 1983). Thus in bamboo plantations, the element potassium is predominant over N, Ca, Mg and P, which is analogous to the effect of slash and burn agriculture on plant nutrients in central Amazonia (Brinkman and Nascimento 1973), in a Costa Rican wet forest site (Ewel et al. 1981), in south America, and in *Dendrocalamus strictus* (Toky and Ramakrishnan 1983) in India. However, the total accumulation of potassium in 6-year-old *Bambusa bambos* in the present study was 5–10% higher than that reported by previous workers.

On unit area basis, the maximum amount of all nutrients was found un culm followed by branches, rhizome and leaves. Therefore the drain of is highest followed by N, Mg, Ca and P, as in *Dendrocalmus hamiltonii* (Toky and Ramakrishnan 1982), where as in *Dendrocalamus hamiltonii, Bambusa tulda, Neohouzeua dulloa* and *Bambusa khasiana* the maximum retention was in the order of K>N>Ca>Mg>P (Rao and Ramakrishnan 1989). Since the annual nutrient content is usually followed by biomass expansion (average annual production), it increases linearly during the period of rapid growth and diminishes at maturity (Pritchett 1979).

Inventory of nutrients

Little has been known previously about the role of bamboos in the cycling and conservation of nutrients in suc-

cessional communities (Toky and Ramakrishnan 1982). However, in plantation bamboo, this study has shown that the bamboo collectively accumulated more nutrient elements than in comparison with order studies (Greenland and Kowal 1960; George 1977; Field 1983; Gessel and Turner 1974; Reiner and Reiner 1970; Rodin and Bázilevich 1967, Woodwell et al. 1975; Grubb and Edwards 1982). Though element storage in the biomass and recycling through litter increased with age, element turnover rates varied. Annual nutrient accumulation improved with age and the enrichment ratio for all elements, which showed an improvement with age, was in general agreement with earlier reports on *Dendrocalamus hamiltonii*, *Neohouzeua dulloa* and *Bambusa Khasiana* (Rao and Ramakrishnan 1989). This study showes that bamboos follow a strategy of faster uptake and storage of essential elements but a slower turnover to supplement the soil. Hence, necessary precautions need to be observed during exploitation of large-scale plantations of *Bambusa bambos* to maintain the fertility status of the soil.

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Bioproductivity and nutrient cycling in bamboo and acacia plantation forests

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Abstract

This study mainly aimed to investigate the bioproductivity and nutrient cycling processes in plantation forests of bamboo and acacia. In India, multipurpose tree (MPT) species are extensively planted to meet the increasing demand for fuel and industrial wood. The bioproductivity studies of bamboo showed that the total biomass increased with age (2.2 t/ha/year 1) up to six years (297.8 t/ha/year 6) and then decreased (15.6 t/ha/year 10). With acacia, the total biomass increased from 1.8 t/ha/(year 1) to 5.0 t/ha/(year 3) and 10.9 t/ha/(year 5). In general the biomass increased with increase of diameter and height. Nutrient cycling in the plantation on an annual basis was worked out. A complete harvest of bamboo in 6 years removes 2341 kg/ha of nitrogen, 22 kg/ha of phosphorus, 2653 kg/ha, of potassium, 1211 kg/ha of calcium and 1356 kg/ha of magnesium. A total harvest of above ground biomass of acacia in 3 years removes (kg/ha) 91.74 N, 2.53 P, 73.41 K, 110.45 Ca, 14.06 Mg, and in 4 years removes (kg/ha) 227.47 N, 7.34 P, 181.04 K, 284.15 Ca, and 38.89 Mg. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Bioproductivity; Nutrient cycling; Bamboo; Acacia; Plantations

1. Introduction

Multipurpose tree species are extensively raised to meet the increasing demands for fuel and industrial wood and have assumed much importance due to successful afforestation of the barren areas in the country. To assess the growth performances of a species, it is important to study the productivity and nutrient dynamics, (George, 1977). Biomass studies are important to judge the performances of the species in terms of total biological production and to assess the nutrient drain during harvest (Negi, 1984). Many studies have reported the biomass and nutrient dynamics in several forest species (George, 1977; Shanmughavel, 1995; Anbazhagan, 1998). This study was mainly aimed to study the bioproductivity and nutrient cycling of planted bamboo and acacia.

2. Methods

2.1. Bamboo plantations

2.1.1. Study area

The study site of plantation of *Bambusa bambos* was located at Kallipatty between 11°8′ and 12° of latitude and 76°59′ and 77°47′ longitude, 540 m above m.s.l. The soil was an alfisol and had a pH between 7.4 and 7.8. The concentrations of nitrogen, phosphorous, potassium, calcium and magnesium were 3800, 360, 3600, 1600 and 1800 kg/ha, respectively. The mean temperature was 31°C and annual rainfall was about 600 mm.

2.1.2. Preparation of nursery and planting

A nursery bed of 10 m × 5 m was prepared and filled with a mixture of soil and sand (3:1). Seedlings, raised by tissue culture techniques, were procured from Chithode, Erode and Tamil Nadu. When they were about 7 cm in height, seedlings were removed from their polythene bags, and about 25–30 seedlings were transplanted in the nursery bed. The seedlings were irrigated 2–3 times a day. Care was taken to avoid excess saturation. Nursery beds were provided with a coconut thatch to protect the seedlings from direct sunlight.

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2.1.3. Transplantation

The seedlings in the nurseries were carefully uprooted and transplanted on to the field during August (after about 9 months). The seedlings were planted at 6 m × 6 m spacing in a 3 ha area with a total of 277 seedlings/ha. The transplanted seedlings were irrigated 2 h regularly twice a day. Weeding was done as and when required. After one year, the irrigation was restricted to 15 days interval. Care was taken to avoid water logging and the area was protected against rodents and grazing and browsing animals.

2.1.4. Production of culms

All transplanted seedlings produced rhizomes, from which lateral culms emerged which are the chief components of the total biomass yield. The total number of culms developed from the rhizomes constituted a clump. The productivity of bamboo was assessed by the number of culms produced per annum. At a given site production of new culms depended on the culms of the previous year, the degree of congestion and the clump age.

2.2. Acacia plantations

2.2.1. Study site

The study area (1 ha) of *Acacia holsericea* plantation is located in the foot hills of Maruthamali (11°1′N latitude and 76°93′E longitude) near Bharathiar University, Coimbatore, at an altitude of 410 m above m.s.l. This area has red soils with pH between 7 and 7.6 and electrical conductivity 0.2 mho. The environmental temperature ranged from 27.9°C to 35.7°C with an annual rainfall of 55–650 mm. The soil nitrogen, phosphorus, potassium and magnesium, were 98, 7.6, 175, 70 and 77 kg/ha, respectively.

2.2.2. Plantation details

Seedlings obtained from the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore were used for this study. Seedlings were planted at a spacement of 2 m × 2 m with a total of 2500 seedlings/ha. The transplanted seedlings were adequately irrigated for a month, after which irrigation was stopped and watering left to the monsoon. Nearly 80% of the seedlings survived and grew well.

2.3. Biomass studies

2.3.1. Bamboo

To estimate the total biomass, 15 culms were randomly selected from each age group of plantations. For economy reasons, rhizomes were excavated only from three samples of each age to a total of 18. After felling, the total height of each culm, diameter at breast height (DBH), basal diameter, the number of nodes, were measured and the plants sub-divided into four main components leaves, branches, culm and rhizome. For determination of underground biomass rhizomes were excavated by making a trench around the culm. Fresh weight of the culms and rhizomes were determined in the field and sub-samples were then oven dried (103 ± 2°C) to a constant weight. From the oven dry weight of the samples, the total standing biomass (t/ha) of each age group was calculated. The annual biomass production (total biomass divided by age) and mean periodic production (the difference between biomass measurement of two stands in sequence divided by the age interval) and net primary productivity were estimated (Kadeba, 1991).

2.3.2. Acacia

Field studies were conducted using the stratified tree harvesting method (Art and Marks, 1971). The total number of trees present in the entire study area was counted. The basal diameter, DBH and height of all standing trees within the entire plot (1 ha) were recorded. The entire diameter range in each plantation was divided into three diameter classes designated as A, B and C. The sample trees were selected as being nearest to the average of each class (Ovington et al., 1967).

In each plantation 18 sample trees (6 from diameter class) were felled. Immediately after felling the tree height was recorded and sub-divided into phyllodes, twigs, branches and main bole. For estimating root biomass, a pit was dug out around the tree and care was taken to excavate the entire root of each sample tree. The fresh weight of the components was estimated in the field and representative samples of phyllodes, twigs, branches, main bole and root samples were collected and brought to the laboratory. They were oven dried at 80°C for 48 h, for estimating the dry weight. From the oven dry weight of the samples, the total standing biomass (t/ha) of each age group was calculated.

2.3.3. Nutrient analysis

Nitrogen and phosphorus were estimated (Armstrong et al., 1967) using a Technician Auto analyzer – II (Gedko international, UK), in a kjeldatherm digestion system KT 408 (Bonn) at 400°C for 3 h. One gram sample was digested with 2.5 g potassium sulphate and 5 ml conc. H_2SO_4. After digestion and cooling, the sample was diluted and used for the analysis of nitrogen and phosphorus. K, Ca, Mg were determined using an atomic absorption spectrophotometer (Perkin Elmer 5000 USA) after wet digestion of a 1 g sample with triple acid mixture (10 ml of conc. HNO_3, 4 ml of $HClO_4$ and 1 ml of conc. HCl). The digested samples were filtered through Whateman No. 42 filter paper and made up to 100 ml with distilled water and this solution was stored and used for analysis (Issac and Johnson, 1975).

3. Results and discussion

3.1. Biomass studies

3.1.1. Bamboo

3.1.1.1. Organic matter in sample culms. In plantation bamboo, above ground biomass increased concomitant with DBH and height. In natural forests the culm biomass of *Phyllostachys edulis*, *Phyllostachys reticulata*, was found to be less than their counterparts of plantation stands. The culm biomass of *Dendrocalamus strictus*, *Bambusa arundinaceae*, and *Melocanna baccifera* was higher than *Phyllostachys* species (Ueda, 1960). In comparison with natural forest, plantation bamboo showed 19–85% more culm biomass.

With regard to the percentage contribution of leaves, branches and culms components to the above ground biomass, the plantation age was an important factor. The percentage contribution of leaf (7–1%) decreased with increasing age. No definite trend existed for branch. The percentage contribution of rhizome to grand total biomass correlates with leaf (Othman, 1993).

3.1.1.2. Total biomass. Annual biomass yield of 3–4 year old, air-dry plantation bamboo/ha was 6–7 t/ha for *Bambusa vulgaris* and 1.0 t for *Gigantochloa aspera* (Chinte, 1965). The above ground biomass of *Gigantochloa scortechnii* from Malaysia was 36.36 t/ha in a 3-year old plantation (Othman, 1993). This is lower than 3-year old plantation stand (47.48 t/ha) of this study at Kallipatty.

3.1.1.3. Below ground and above ground biomass ratio. The below- and above-ground biomass ratio between 1 and 6 years of plantation bamboo varied from 0.69 to 0.04. This ratio varies with plant species and age (Kaul et al., 1983).

3.1.1.4. Net primary production. The net primary production and mean annual biomass accumulation depended on stand age. In 5-year plantation bamboo 124.08 t/ha/yr was attained.

3.1.1.5. Dry-organic matter density. The dry-organic matter density approximately ranged between 1 and 10 kg/m^3 i.e., higher than in other bamboo species (0.52–0.88 kg/m^3) including *Gigantochloa scortechnii* (0.54–0.55 kg/m^3) (Othman, 1993).

3.1.2. Acacia

3.1.2.1. Dry matter production of sample tree. The proportion of the biomass of main bole, branch, twig, phyllode and root changed with tree size and stand age. As the stand age increased, the main bole weight constituted an increasing proportion of the total biomass, varying from about 40% (year 1)–59% (year 5) (DBH class C). In contrast, the proportion of total biomass channeled to branches, twig and phyllodes decreased with stand age, which corroborates the results of other studies (Bradstock, 1981; Jokela et al., 1981; Pinyopusarerk, 1989; Kadeba, 1991).

3.1.2.2. Total biomass. The total above ground standing biomass in *Acacia holosericea* plantations was in the order of 1.5, 10.3 and 24.1 t/ha at the year 1, 3 and 5, respectively, which indicated a proportional increase of biomass with age. Compared to *Acacia* species, *A. auriculiformis*, *Acacia Senegal*; *A. auriculiformis*, *A. julifera*, *A. shirlefera*, *A. shirleji*, and *A. ampliceps* (Sahoo et al., 1991; Osman et al., 1992) the present estimates were 1.5–3.5 folds lower. This perhaps may be due to low rainfall in the study area. So it may be inferred that the biomass accumulation of acacia species ultimately depends on the rainfall. Compared with other tree species 16.3 t/ha in *Leucaena leucocephala* in the year 5 (Pandey et al., 1989); 18.11 and 21.9 t/ha *E. citridora* in the year 7 (Hossian et al., 1997); 22.5 t/ha in the year 5 *Populus deltoids* (Negi, 1984), the estimated biomass was 1.5 times higher. The below- and above-ground biomass ratio between year 1 and 5 plantations varied from 5.3 to 5.5. The young plant (year 1) developed vast lateral roots from their below ground parts and provided the much needed water and nutrient requirements to the plant. In older plants (year 5) the aerial parts were more developed than under ground parts (Kushalapa, 1984).

3.2. Nutrient cycling

3.2.1. Bamboo

Nutrient cycling in the plantations on an annual basis was worked out. Of the total uptake 94% N, P, Ca and Mg was retained in the non-photosynthetic biomass and 6% returned. A complete harvest (above ground biomass) of *B. bambos* at the age of 6 years removed 2431 kg/ha, of N, 222 kg/ha of P, 2653 kg/ha of K, 1211 kg/ha of Ca and 1356 kg/ha Mg from the site. Studies on the nutrients uptake and their accumulation revealed that essential nutrients were removed from the soil at the rate of 62–74%. Thus the present study stresses the importance of the application of the external fertilizers after the harvest of the biomass components.

3.2.2. Acacia

The estimated gross annual accumulation of nutrients of the *A. holosericea* stand was found in decreasing order of Ca (284.15 kg/ha), N (222.47 kg/ha), K (181.04 kg/ha), Mg (38.89kg/ha) and P (7.34kg/ha). The transfer of nutrients in the litter was in order of N (12%), Mg (10.2%), P (8.5%), Ca (6.5%) and K (6.2%). Similar nutrient cycling had been observed in *A. nilotica*, *A. auriculiformis* (Chaturvedi and Behal, 1996), *A. catechu* (Singh and Singh, 1993), *A. saligna* and *A. cyclops*

(Stock et al., 1995) and *A. magnium* (Xu et al., 1994). The cycling of nutrients is an annual process controlled by litter fall. Unlike *E. globules*, *E. grandis*, *D. sisso*, *P. patula* (Madgwick et al., 1977; Turner and Lambert, 1983) nutrients in *A. holosericea* are utilized more than returned.

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The dynamics of biomass and nutrients in bamboo (*Bambusa bambos*) plantations

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Abstract- -Bamboo is presently one of the dominant species used in India for plantation. The aim of this research was to obtain quantitative data on the biochemical functioning of the bamboo plantation ecosystem and to provide relevant information to foresters. The results presented here concern biomass and nutrient accumulation in an age series of a bamboo plantation. In particular, to obtain information on ecosystem dynamics, an age series of 1 to 10 years was studied because it is possible that these stands will reveal the assimilation characteristics of different ages and different stages of development in a single plantation.

The biomass production in an age series of *Bambusa bambos* plantation were estimated and compared with its inter species and between genera of natural and plantation stands. There was linear increase of the total biomass of all compartments with the age of the plantation up to six years and then it decreased. In the above ground biomass, the relative percentage contributions were: culms (81%), branches (14%) and leaves (1%). The below ground rhizome contribution was 4%. The total biomass increased from 2.3 t/ha (1 year) to 298 t/ha (6 year) and decreased to 16 t/ha (10 year). The percentage of nutrient distribution in different biomass components varied: the order of major element concentrations was K > N > Mg > Ca > P in leaves. The maximum amount of all nutrients per hectare occurred in the culms, followed by branches, rhizomes and leaves. The present results make it possible to evaluate with sufficient accuracy nutrient losses at crop harvest. These results could be introduced in management models.

Key words: Bamboo plantation; age series; biomass nutrient content; nutrient distribution; nutrient retained.

1. INTRODUCTION

Bamboo, which are giant, woody, tree-like grasses have a long history as an exceptionally versatile and widely used resource. India possibly has the world's richest resources of bamboo with some 130 species occurring over an area of 10.05 million hectares [30]. The diverse bamboo plantations in the natural habitat are dwin-

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dling, due to over-exploitation, shifting cultivation practices and extensive forest fires. Sustained availability can be ensured only by intensive bamboo cultivation for industrial purpose. One promising species for such cultivation is *Bambusa bambos* (L.) Voss., which is planted for long-fibred pulpwood production [28].

The lack of information of nutrient requirements and effects of bamboo silviculture on the environment spursed us to investigate this field. Worldwide research on nutrient cycles has been carried out at one particular stage of stand development, generally on the mature stage [9, 34]. More relevant information in the field of nutrient dynamics according to plantation stand development needs to be obtained.

This work is part of a general investigation, the aim of which is to determine the ecological basis for stand management and to identify the effects of bamboo plantations on the environment and particularly on soils. The total loss of nutrients from the ecosystem by biomass harvesting and by deep drainage will be evaluated and the potential of the soil to supply these elements will be investigated to prevent soil nutrient depletion and to ensure the perenniality of the production.

This particular part of the study will be focused on the effect of plantation age on biomass production, nutrient uptake and distribution.

2. MATERIALS AND METHODS

2.1. Practical organisation of the project

2.1.1. Nursery management practices and transplanting. Since bamboo seeds possess a short period of viability (a few days to 1 month), seedlings from tissue culture were employed for raising bamboo plantations. A nursery area of 10 × 5 m was prepared in the field and filled with a mixture of soil and sand (3 : 1). The seedlings were picked out from the polythene bags when about 7 cm in height. About 25–30 seedlings were planted in 1 m^2 of raised nursery bed. Watering was done 2–3 times a day and care was taken to avoid over saturation. Nursery beds were provided with a thatch to protect the seedlings from direct sunlight.

The seedlings in the nursery were uprooted carefully and transplanted to the field. The seedlings were planted at 6 × 6 m spacing with 250 seedlings per ha. The transplanted seedlings were watered every 2 h regularly in the morning and evening. Weeding was done as and when required. After 1 year, the plantation was adequately irrigated at 15-day intervals. Care was taken to avoid waterlogging. The plantation was protected against damage by rodents, and grazing and browsing animals.

2.1.2. Annual recruitment of culms. The number of new culms produced annually assesses the productivity of bamboo. At a given site the production of new culms mostly depends on the culms of the previous year, the degree of congestion and the clump age. In the trial plantation at Kallipatty, Tamil Nadu State, India culm emergence took place the year following planting. Seedlings of *Bambusa bambos*

produced only five culms per clump in the first year after planting. The average number of culms gradually increased in the subsequent years. Culms emerging in the first year were short (1.4 m) in length and small in diameter (2.3 cm at breast height). Culms produced in subsequent years were distinctly taller and thicker.

2.1.3. Ecological situation. The 10-year plantation of *Bambusa bambos* studied was located at Kallipatty, Tamil Nadu, which lies between 11°28′ to 12° E latitude and 76°9′ to 77°47′ N longitude. Its altitude is 540 m above mean sea level. This area soil was laterite, red to brown in colour and sandy loam in texture [35]. The soil moisture content was determined by drying 10 g fresh soil in a hot-air oven at 150°C for 24 h. The pH (7.4–7.8) was observed on an electric digital PH-meter in a 1.5 (w : v) soil–water suspension. For N, P and K, the samples were air dried and sieved (0.2 mm). Total N was estimated by the indophenol blue method described by Allen [1]. The molybdenum blue method of Jackson [16] was followed to determine the available soil P. Potassium was extracted from the soil in an ammonium acetate solution (pH = 7) and was measured with a digital flame photometer (Systronics 121, India). To obtain the total soil nutrient concentrations per hectare, the percentage nutrient content was divided by 100 and the result multiplied by 2 million. One hectare usually contains 2 × 106 kg of soil [10]. The total soil concentrations of N, P, K, Ca and Mg were 3800, 360, 3600, 1600 and 1800 kg per ha, respectively. Mean temperature and rainfall for the site are 31°C and 600 mm, respectively.

2.1.4. Methodology to evaluate biomass. A special method was progressively adopted to accurately evaluate the biomass and mineral content of forest stands [3, 22, 23].

For the present study, the biomass estimation method can be summarized as follows. In order to estimate the total biomass, in relation to organic productivity, 15 culms were randomly selected from each age group. For reasons of economy, the rhizome was excavated from only 3 in each age group After felling, the total height of each culm, diameter at breast height (DBH), basal area and number of nodes were measured and subdivided into leaves, branches, culm and rhizome. Fresh weight of the components was estimated in the field and the sub-samples from each component were brought to the laboratory in plastic bags. The sub-samples were then oven dried at 103 ± 2°C at constant weight. From the oven-dry weight of the samples, the total standing biomass of each age group was calculated by multiplying the total number of the bamboos of different ages with the average dry weight of the sample.

2.1.5. Nutrient analysis. The bamboo was reduced to sawdust by means of an electrical saw. The sawdust was sieved initially with 65 meshes per cm^2 and later with 200 meshes per cm^2. The materials retained during the second sieving was called 'average wood' and was used for the analysis (the wood used for the analysis

was dry). Nitrogen and phosphorous were estimated as described by Armstrong *et al.* (1976) using the Technician Autoanalyser II (Gedko International, UK). The sample was digested in a Kjeldathern digestion system KT 408 (Bonn) at 400°C for 3 h. A 1 g sample was digested in digestion tubes with 2.5 g potassium sulphate and 5 ml H_2SO_4. After digestion and cooling, the digested sample was made up to 100 ml with distilled water and used for analysis of N and P. The nutrients K, Ca and Mg were analysed using an atomic absorption spectrophotometer (Perkin-Elmer 5000, USA) after wet digestion of a 1-g sample with a triple acid mixture (10 ml conc. HNO_3, 4 ml HC 104 and 1 ml conc. HCl). The digested samples were filtered through Whatman No. 42 filter paper and made up to 100 ml with distilled water and this solution was stored and used for analysis [15]. All analysis was performed on the average of three replicates.

3. RESULTS

3.1. Biomass production

It is seen in Table 1 that there was a linear increase in the biomass of all compartments with the age of the plantation up to six years. The culm height increased from 1.4 m to 28.5 m in six years concomitant with the expansion in diameter from 2.3 to 8.3 cm. The total biomass also increased from 2.3 (year 1) to 298 t/ha (year 6). In leaves, biomass increased from 0.166 in the year 1 to 4.0 t/ha in the year 6 which was 24.2 times higher. The branch biomass increased from 0.5 to 39 t/ha in the 6th year, a factor of 80.9. The total above ground biomass (culm, branch, leaves) increased from 1.3 t/ha to 286 t/ha, a factor of 211.3 times. However, the below ground biomass (rhizome) increased from 0.9 t/ha to 11.2 t/ha, which was 11 times higher. In all components, a decrease in biomass accumulation was noticed after the sixth year.

3.2. Nutrient concentration in different components

In Tables 2–5, the average nutrient concentration of four components of bamboo for all six age groups is given. The highest concentration of different nutrients in the various biomass components was generally observed in the order of leaf, branch, culm and rhizome. The proportions of nutrient elements were in the order K > N > Mg > Ca > P except for leaf in which the nutrient elements were found in the order N > K > Mg > Ca > P.

3.3. Distribution of nutrient elements in different components

The distribution of elements in the leaf, branch, culm and rhizome are calculated. The leaf contained 33–36% N, 3–4% P, 31–35% K, 10–16% Ca and 15–17% Mg. The branches contained 31–37% N, 3–4% P, 35–37% K, 10–15% Ca and 11–18% Mg. The higher concentrations were observed in the culm, which

Table 1.
Production of biomass in *Bambusa bamboo* plantation (t/ha)

Age	Culm diameter (cm)	Culm height (cm)	Basal area (cm)	No. of culm	No. of codes	Biomass (t/ha)			Total above ground biomass	Rhizome biomass	Grand total biomass
						Leaf	Branch	Culm			
1	2.3	1.4	3.1	1250	7	0.166	0.493	0.698	1.356	0.938	2.294
2	3.3	3.2	4.0	2250	16	0.668	1.897	6.795	9.360	3.150	12.510
3	4.3	9.6	5.0	3000	37	1.122	17.11	29.25	47.487	4.980	52.467
4	4.8	21.8	6.1	3500	86	1.862	27.16	92.75	121.772	6.055	127.827
5	6.3	27.2	8.3	4000	98	3.544	33.94	187.23	224.708	9.600	234.308
6	8.3	28.5	101.1	4250	103	4.021	39.89	242.73	286.637	11.220	297.857
7	5.4	20.5	6.0	3250	81	1.898	21.10	116.95	139.954	8.245	148.199
8	4.1	16.0	5.4	2750	66	1.380	15.66	68.82	85.856	5.390	91.246
9	2.8	8.5	3.6	1500	44	0.477	6.455	20.79	27.732	2.040	29.772
10	2.5	7.4	3.0	900	37	0.246	2.853	11.43	14.259	1.143	15.672

Results are the average of three independent observations. Since there was little difference between observations, average values [illegible] n.

Table 2.
Nutrient concentration in the leaves

Nutrients Mg/g-1	1	2	3	4	5	6	7	8	9	10
N	7.9	8.8	9.0	9.3	9.7	10.5	9.2	8.5	7.7	7.3
P	0.8	0.8	0.9	0.9	1.0	1.0	1.0	0.9	0.9	0.9
K	7.6	8.2	8.7	9.0	9.5	1.0	9.0	8.0	7.5	6.9
Ca	2.3	2.9	3.3	3.8	4.4	5.1	5.0	4.5	4.3	4.0
Mg	3.4	3.7	4.3	4.9	5.2	5.4	5.2	4.9	4.5	4.5

Results are the average of three independent observations. Since there was little difference between observations, average values are given.

Table 3.
Nutrient concentration in the branch

Nutrients Mg/g-1	1	2	3	4	5	6	7	8	9	10
N	6.5	6.7	7.0	7.9	8.3	8.9	8.5	8.0	7.6	7.0
P	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.8	0.8	0.8
K	6.7	7.3	7.8	84	8.9	10.0	9.5	8.8	8.4	7.9
Ca	2.0	2.3	2.9	3.1	3.8	4.3	4.0	3.5	3.3	3.0
Mg	3.0	3.2	3.8	4.0	4.6	4.8	4.5	4.0	3.8	3.5

Results are the average of three independent observations. Since there was little difference between observations, average values are given.

Table 4.
Nutrient concentration in the culm

Nutrients Mg/g-1	1	2	3	4	5	6	7	8	9	10
N	6.0	6.4	6.7	7.4	7.8	8.2	8.0	7.5	7.3	7.0
P	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.7	0.7	0.7
K	6.4	6.9	7.4	7.9	8.2	8.9	8.5	8.0	7.8	7.5
Ca	1.8	2.3	3.0	3.6	3.9	4.1	4.0	3.7	3.5	3.0
Mg	2.9	3.3	4.1	4.3	4.4	4.6	4.3	4.0	4.0	3.5

Results are the average of three independent observations. Since there was little difference between observations, average values are given.

contained 30–34% N, 3–4% P, 33–36% K, 10–15% Ca and 17–19% Mg in the aerial shoots of 1–10 year aged-plantation *Bambusa bambos*.

3.4. Nutrient retention

The average annual nutrient retention was obtained by multiplying the productivity of biomass components with their respective nutrient concentration (Fig. 1). It

was observed that, on a unit area basis, the maximum amount of all nutrients was

Table 5.
Nutrient concentration in the rhizome

Nutrients Mg/g-1	1	2	3	4	5	6	7	8	9	10
N	5.7	6.0	6.3	6.9	7.3	7.7	7.2	6.8	6.3	6.0
P	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.6	0.6
K	6.0	6.4	6.9	7.3	7.9	8.4	8.0	7.5	7.2	6.8
Ca	1.6	2.0	2.9	3.4	3.6	3.9	3.5	3.0	2.5	2.3
Mg	2.5	2.7	3.1	3.5	3.9	4.3	4.0	3.8	3.3	3.0

Results are the average of three independent observations. Since there was little difference between observations, average values are given.

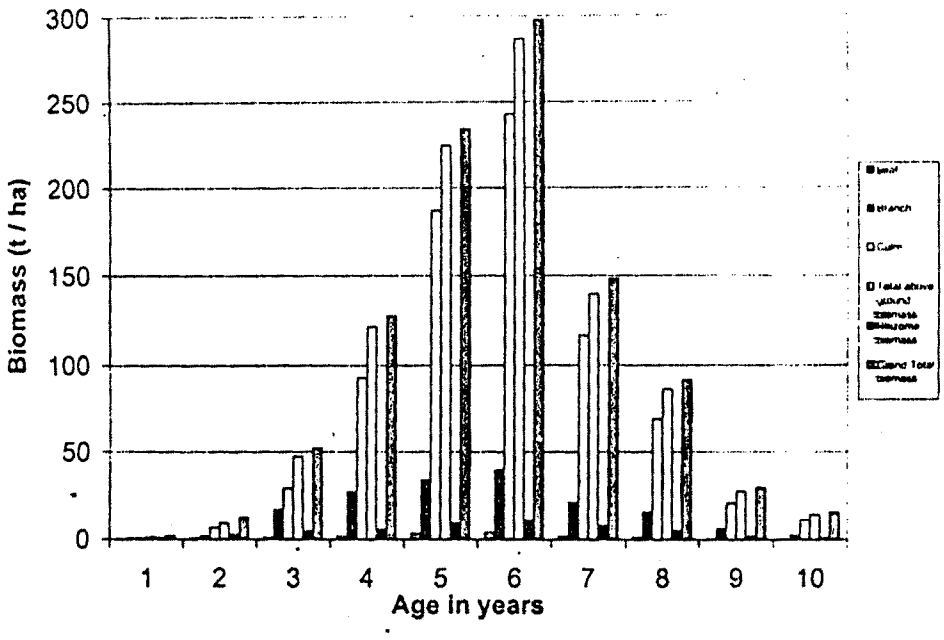

Figure 1.

found in culm followed by branches, rhizome and leaves. Therefore the maximum drain of all nutrients occurred through culm harvest and, among the nutrients, the maximum drain occurred in potassium followed by nitrogen, magnesium, calcium and phosphorus.

4. DISCUSSION

4.1. Biomass production

The biomass (dry matter) of each plantation increased with age as expected. This increment was more prominent in the culm than the other parts of the bamboo. It

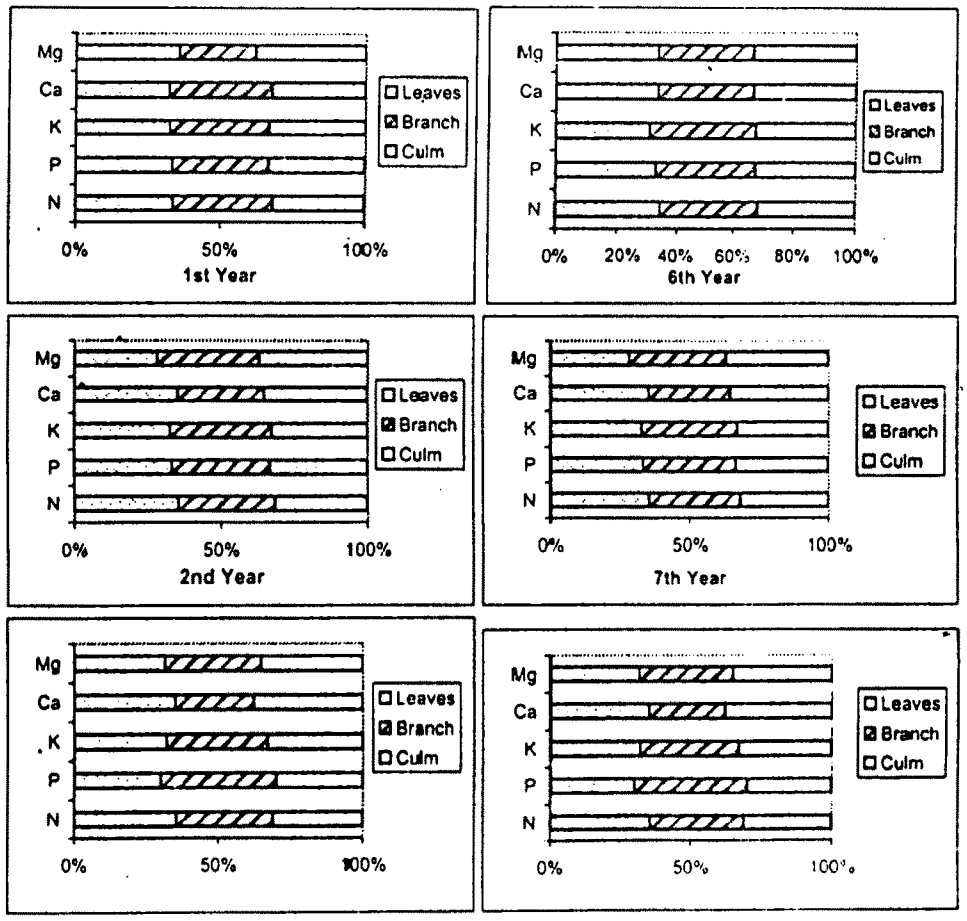

Figure 2.

was observed that the above-ground biomass increased progressively and amounted to 286 t/ha (year 6) and then decreased to 16 t/ha (year 10). Compared with the measured biomass the annual yield of bamboo per ha of the 3 to 4 years old plantation was found to be 7 t/ha for *Bambusa vulgaris* and 1 t/ha for *Gigantochloa aspera* [5]. The above-ground biomass of the plantation was 85% higher. The above-ground biomass of the *Gigantochloa scortechnii* from Malaysia was 72 t/ha in a natural stand and 36 t/ha in a 3 year old plantation [19]. Compared with the biomass of other fast growing tree species — 8 t/ha in the 4 year old *Eucalyptus globulus* [6], 47 t/ha in 5 year old *Leucaena leucocephala* [20] and 87 t/ha in 6 year old *Pinus caribea* [17], the present biomass estimates were 7–30% higher.

4.2. Nutrient dynamics

The nutrients retained in the average annual production were obtained by multiplying the increase in biomass components by their respective nutrient concentration. The nutrient contents of the standing crop differ substantially between various for-

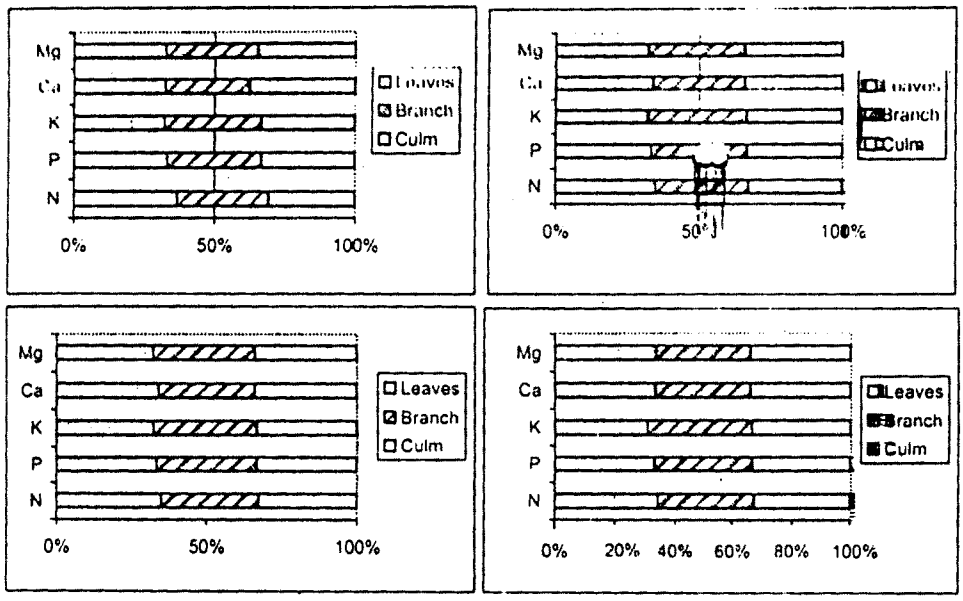

Figure 2. (Continued).

est types according to the degree of uptake and crop biomass, which in turn depend on the age and site quality even within the same species. The increase in nutrient contents of the standing crop with stand age observed in this study has a direct relationship of the biomass of a forest stand [27]. As such, the nutrient accumulated in various tree components varied considerably.

The concentration of nutrients in the aerial shoots and rhizome increased with age. The nutrients elements in leaf were in the order of N > K > Mg > Ca > P, while in branch, culm and rhizome the order was K > N > Mg > Ca > P. These are in general agreement with results for *Dendrocalamus hamiltonii* [33] and *Bambusa balcooa*, *Dendrocalamus strictus* and *Thyrsostachys oliveyi* [32]. In *Bambusa khasiana* the order was K > N > Mg > Ca > P [25].

Among the cation concentrations, that of potassium was the highest. In this context, bamboo plays an important role in the conservation of potassium because of its capacity for rapid uptake and accumulation. Of the total accumulation of nutrients over 6 years, potassium alone contributed about 51%. The weight of elements increased linearly with biomass [32]. Thus in bamboo plantations, the element potassium is predominant over N, Ca, Mg and P, which is analogous to the effect of slash and burn agriculture on plant nutrients in central Amazonia [4], in a Costa Rican wet forest site [7] in South America, and in *Dendrocalamus strictus* [33] in India. However, the total accumulation of potassium in 6-year-old *Bambusa bambos* in the present study was 5–10% higher than reported by previous workers.

Nitrogen in leaf was found proportionately higher in the present study. Higher allocation of nitrogen to the leaf component may be related to photosynthetic

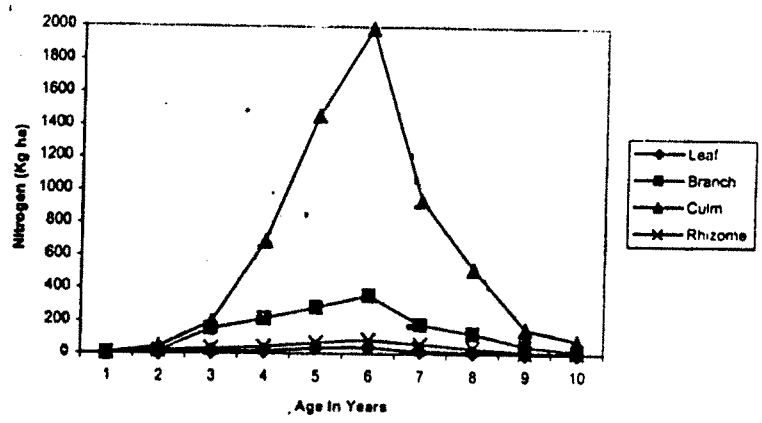

Figure 3.

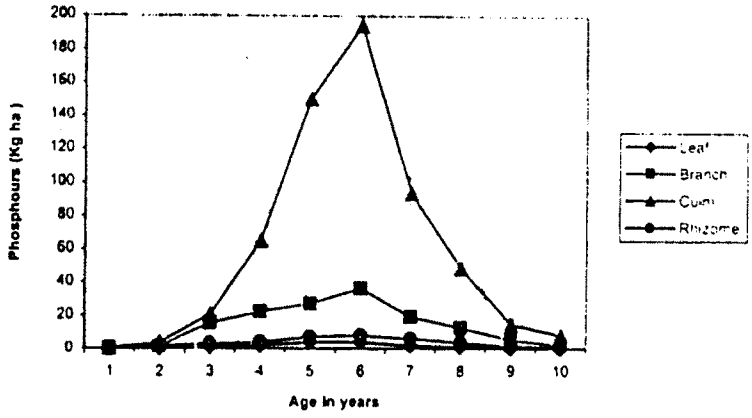

Figure 4.

efficiency, since leaf nitrogen is positively related to photosynthetic rate [8, 18, 31] Natr, 1975; Rao and Ramakrishnan, 1988. In *Dendrocalamus hamiltonii* [33], potassium replaced to leaf nitrogen followed by branches and culms. Annual uptake of calcium and magnesium was higher in comparison with other fast growing tree species [9, 34], Hingston *et al.*, 1988; Negi and Sharma, 1984.

The percentage allocation of nutrients in different compartments of aerial parts of the stand was calculated on a hectare basis and compared. These was a close relation in percentage allocation of dry matter to different compartments of the bamboo which was related to the age of the stand. In a young stand of *Bambusa bambos* of one year old 30% and 7% of dry matter was in the culm and in leaves respectively. Distribution of N, P, K, Ca and Mg was between 4 to 34% in the culm and 4 to 36% in leaves, indicating more allocation of nutrients to the latter. In a six year old stands dry matter and nutrients were more towards the bole than the leaves. With increase in stand age, shift in the nutrient allocation was more towards the bole which reveals more dry matter production in the bole than others [17, Ovington, 1957].

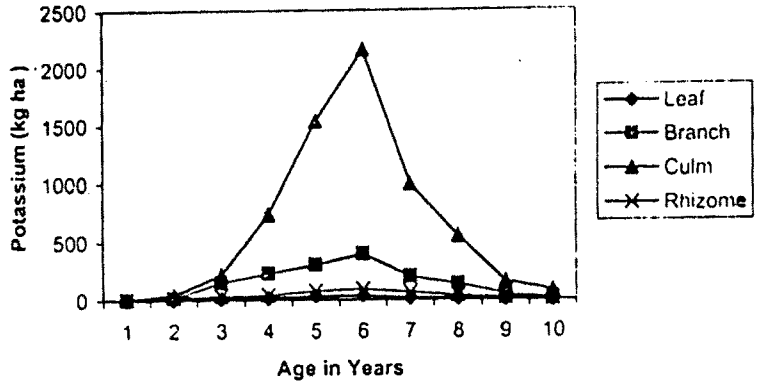

Figure 5.

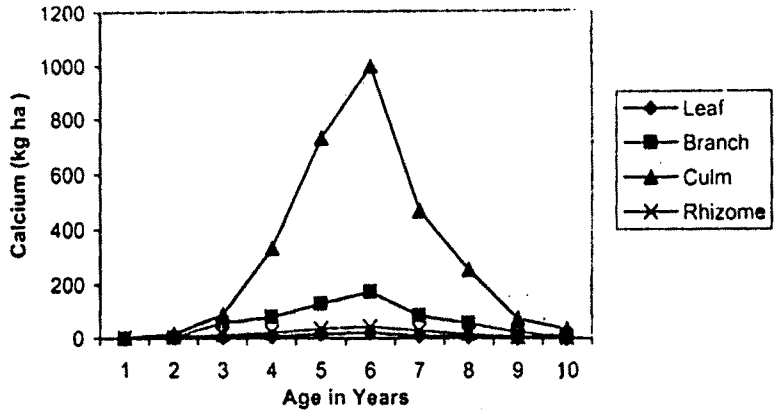

Figure 6.

On unit area basis, the maximum amount of all nutrients was found on culm followed by branches, rhizome and leaves. Therefore the nutrient drain is highest for K followed by N, Mg, Ca and P as in *Dendrocalamus hamiltonii* [33], whereas in *Dendrocalamus hamiltonii, Bambusa tulda, Neohouzeua dulloa* and *Bambusa khasiana* the maximum retention was in the order of K > N > Ca > P [25]. Since the annual nutrient content is usually followed by biomass expansion (average annual production), it increases linearly during the period of rapid growth and diminishes at maturity [21]. The same holds true for *Bambusa Bambos* plantations, where the average annual production is maximum at 6 years of age and similarly the annual accumulation of nutrients also attains a peak a value. These results are in general agreement with earlier observations (Walls and Jorgenson, 1975; Negi and Sharma, 1984).

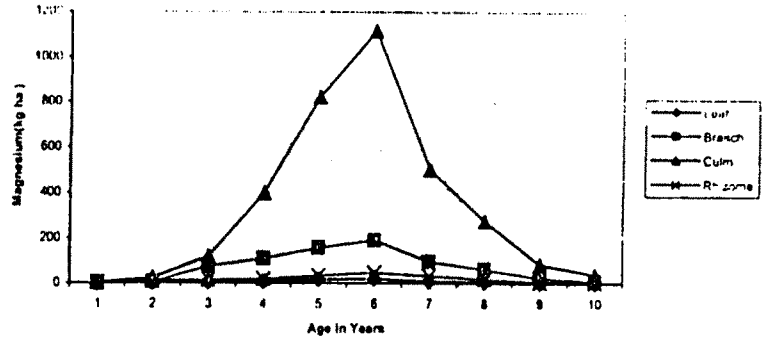

Figure 7.

5. CONCLUSION

An age series of bamboo stands is a useful tool to obtain pertinent information on ecosystem functioning. The plantations selected for this study provide relevant information for accumulation of biomass and nutrients by bamboo stands. The biomass accumulation of plantation bamboo is found to be higher than its counterparts in the natural habitats. This conclusion which needs to be confirmed by other studies. Intensification of forest harvest will inevitably lead to soil impoverishment. The present results obtained on an age sequence of stands make it possible to evaluate nutrient losses during harvest with reasonable accuracy. Several scenarios could be drawn using various rotation lengths and harvesting intensities. These results could be introduced in management models. The input-output budgets for the whole rotation will provide useful information, especially concerning the most accurate quantity of fertilizers both for the sustainability of the production and the conservation of the major parameters of the environment.

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Nutrient Return in *Bambusa bambos* Plantations

P. SHANMUGHAVEL*

ABSTRACT

Nutrient return through litter in Bambusa bambos plantations were studied. The highest concentration of N, P, Ca and Mg was in leaf litter. In twig litter maximum concentration of K was recorded. On an annual basis, the total return of Nitrogen was 141 kg/ha followed by 121 kg/ha of Potassium, 79 kg/ha Magnesium, 72 kg/ha Calcium and 131 g/ha Potassium. Maximum amount of all the nutrients were returned through leaf.

Introduction

The recycled nutrients from decomposing forest litter are one of the main nutrient sources for maintaining the growth of forest trees. (Staaf & Berg 1981) Investigations of litter production and the amounts of important nutrients recycled through the litter in plantations of tropical tree species have been published by several workers from India as well as from outside the country. (Singh 1984, Srivastava *et al.* 1972, George 1982, 1988, 1990, Negi *et al* 1984, Ram Prasad *et al.* 1984, Gill *et al.* 1987, Cromer *et al.* 1982, and Rogers & Westmann 1979.) In the earlier article (Shanmughavel 1993) the results of studies carried on litter production of *Bambusa bambos* were discussed. However studies on nutrient cycling in *Bambusa bambos* plantations have not yet been carried out and therefore, the present article deals with the nutrient cycling in a 5 years old *Bambusa bambos* plantations grown at Kallipatty, Periyar District, Tamil Nadu.

Materials and Methods

Studies were carried out from January to December 1993 in a 5 years old plantation of *B. Bambos*. The site, on a red soil is situated about 28 km north of Sathyamangalam (11° 28′ – 12° N and 76° 59′ – 77° E) The climate is monsoonic. The maximum soil nitrogen, phosphorus and Potassium was 176 kg/ha, 33 kg/ha, and 225 kg/ha respectively. The mean temperature was 32°C. Maximum rainfall was 316 mm. The mean relative humidity was 82%.

The sampling area was 1 ha. plantation of pure bamboo stands. Density was 7000 culms/ha. culms were of 25m average height with an average diameter at breast height of 7 cm.

Nine litter plots of 1×5 m size were laid down randomly throughout the sample plot. The litter plots were made permanent by enclosing the area using nylon thread, to last throughout the study period and the plant materials were harvested completely by the end of every month. The contents of the litter plots were brought to the laboratory,

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separated into components dried to constant weight at 80° C and the dry weights recorded.

For chemical analysis (N, P, K, Ca & Mg) of litter, the oven dried material was ground and sieved through 70 mesh. Nitrogen and phosphorus was estimated as detailed by Armstrong *et al* (1967) using Technicon Autoanalyser – II. Calcium, Potassium and Magnesium was determined with a Perkin-Elmer atomic absorption spectro photo meter. (Issac and Johnson, 1975).

Results and Discussion

Nutrients return:

Since there was not much variation in the nutrient concentration of litter components, during various months of the year, the average values were taken into consideration for further discussion. The results on chemical analysis along with standard deviation are given in Table 1. It was seen that the highest concentration of N, P, Ca and Mg was observed in leaf, while twig had the highest concentration of K. It was also observed that, in leaf among the various nutrients N had the maximum percentage followed by K, Mg, Ca and P. These results are in general agreement with those obtained from *E. globulus* by Venkataraman *et al* (1983) *E. Hybrid* George (1982) and *E. globulus*, George and Varghese (1990), where in the highest concentration of all nutrients was in leaf and the highest percentage concentration was for N. The elemental concentration in twig as observed in the order of K > N > Mg > Ca > P.

Table 1
Nutrient concentration in litter components (% oven dry weight)

Litter components	Nutrients				
	N	P	K	Ca	Mg
Leaf	0.94±3.2	0.09±1.0	0.65±7.0	0.47±2.5	0.49±3.5
Twig	0.61±4.5	0.06±0.5	0.73±8.5	0.33±3.0	0.39±3.5

The nutrient return through annual litter fall on unit area basis is given in Table 2. It was seen that 141 kg/ha of N. 13 kg/ha of P 121 kg/ha, of K. 72 kg/ha of Ca and 79 kg/ha Mg is returned to the soil through litter fall. (Fig. 1).

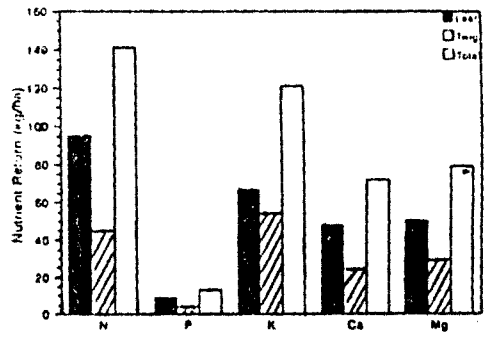

Fig. 1

Table 2
Nutrients return through Litter Fall (kg/ha)

Litter components / Components	Nutrients				
	N	P	K	Ca	Mg
Leaf	96.0	9.0	67.0	48.0	50.0
Twig	45.0	4.0	54.0	24.0	29.0
Total	141.0	13.0	121.0	72.0	79.0

The maximum amount of all nutrients (68% of N, 69% of P, 55% of K, 67% of Ca and 63% of Mg) was returned through leaf litter and minimum by twig litter. Twigs contributed 37% of all nutrients. Almost similar results were also obtained from studies carried out on nutrient return through litter fall in

Table 3

Annual Release of Nutrients (kg/ha/yr) through Litter fall in Different Forest

Forest type and Locality	Nitrogen	Potassium	Phosphorus	Calcium	Magnesium	Source
Spruce (USSR)	52	12	2	48		Soon, 1960
Birch (USSR)	66	13	5	54		Smirnova and Gorodentseva, 1958
Oak (USSR)	59	62	3	86		Mina, 1955
Eucalyptus tereticornis (U.P. India)	14.2-34.5	–	8.6-20.8	98.2-334.5		Singh, 1984
Tectona grandis (U.P. India)	52	19	11	131		Seth *et al* 1963
Shorea robusta (U.P. India)	46	19	9	77		–do–
Pinus sp. (U.P. India)	73	39	13	46		–do–
Butea sp. (U.P. India)	18	6	0.3	15		K.P. Singh, 1968
Piecea smithiana (H.P. India)	46.53	13.61	10.21	56.17		Singh *et al* 1984
Cedrus deodara (H.P. India)	47.78	16.86	28.81	70.97		–do–
Abies pindrow (H.P. India)	44.59	9.0	15.16	52.78		–do–
Pinus wallichiana (H.P. India)	24.45	6.03	7.93	34.93		–do–
Bambusa bambos plantation (T.N. India)	141.0	121.0	13.0	72.0	79.9	Present study

moist deciduous forest by Singh (1968, 1969) Gill *et al* (1987), Srivastava *et al.* (1972) George and Varghese 1990.

A comparative account of nutrients released by different woody species is presented in Table 3 Data reveals that annual release of phosphorus and calcium is comparable to that of the results reported earlier (Seth *et al.* 1963, and Singh *et al.* 1984) The *Bambusa bambos* under this study released annually maximum nitrogen and Potassium than other species under comparison in Table 3. The results of the present study indicate that, *Bambusa bambos* returns substantial quantities of N, K, Ca, Mg and P through litter fall, The twig litter is collected for making padels and other uses. Thus the nutrients contained in the twig litter are not allowed to recycle in the soil and therefore a great drain of nutrients takes place.

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Litter Production in a *Bambusa bambos* Plantation

P. Shanmughavel and K. Francis

Abstract

Litter production was estimated in a five year old *Bambusa bombos* plantation at Kallipatty, Tamil Nadu, India. Maximum litter fall occurred in December (1556 kg ha^{-1}) with a second peak in May (1138 kg ha^{-1}). Minimum litter fall occurred during March (665 kg ha^{-1}). Leaf litter accounted for 58% (10307 kg ha^{-1}) and twigs 42% (7373 kg ha^{-1}) of total annual litter production (17.6 mg ha^{-1} yr^{-1}).

সারসংক্ষেপ

ভারতের তামিলনাড়ু রাজ্যের কাল্লিপাট্টিতে সৃজিত পাঁচ বৎসর বয়সের *Bambusa bambos* বাঁশের লিটার (পাতা ও পল্লব) ঝরার পরিমাণ নির্ণয় করা হয়েছে। সর্বোচ্চ লিটার (১৫৫৬ কেজি/হেক্টর) ঝরে ডিসেম্বর মাসে। পরবর্তী সর্বোচ্চ পরিমাণ লিটার (১১৩৮ কেজি/হেক্টর) ঝরে মে মাসে। সর্বনিম্ন লিটার (৬৬৫ কেজি/হেক্টর) ঝরে মার্চ মাসে। মোট বার্ষিক ঝরাকৃত লিটার (১৭.৬ এমজি/হেক্টর) এর মধ্যে শুধু ঝরাকৃত পাতার অংশ শতকরা ৫৮ ভাগ (১০,৩০৭ কেজি/হেক্টর) ও পল্লবের ভাগ ৪২% (৭৩৭৩ কেজি/হেক্টর)।

Key Words : *Bambusa bambos*, litter production.

Introduction

The forest floor receives a large amount of litter made up of various components (leaves, twigs, branches and barks) directly from the living plants. Nutrients recycled from decomposing forest litter are one of the main nutrient sources for tree growth. Litter also has important effects on soil physical properties. Organic matter reduces bulk density, increases water-holding capacity and cation exchange capacity (Hoyle 1973). Litter accumulation also checks weeds, protects the soil from the erosive impact of rain and reduces surface water run-off. (Singh *et al* 1984). Maintenance of soil organic matter concentrating is especially important in many tropical and sub-tropical soils where organic matter concentrations are low.

Physical, chemical and biological properties of soils are strongly dependent on organic matter concentration. Litter inputs are important because they maintain soil organic matter levels and, therefore, the associated properties.

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A comprehensive review of forest floor litter was given by Bray and Gorham (1964). Annual litter production in plantations of *Dendrocalamus strictus* (Seth *et al.* 1963) and *Neohouzeaua dullooa, Dendrocalumus hamiltonii* (Rao and Ramakrishnan 1988) have been reported, but no data are available on litter production in plantations of *Bambusa bambos* in India. This investigation was conducted to assess litter production in plantations of *Bambusa bambos* at Kallipatty, India.

Materials and methods

Measurements were carried out from January to December 1992 in a 5 year old plantation of *Bambusa bambos*. The site, on a red soil is situated about 28 km north of Sathyamangalam (11°28´ - 12° N and 76°59´ E). The climate is monsoonal. High velocity wind blows during the south - west monsoon. The soil nitrogen, phosphorus, and potassium was 176 kg ha^{-1}, 33 kg ha^{-1}, and 225 kg ha^{-1} respectively. The mean temperature was 32°C. The average rainfall was 316 mm. The mean relative humidity was 82 percent.

The sampling area was a plantation of pure bamboo. Culm density was 7000 culms ha^{-1}. Culms were of 25 m average height with an average diameter at breast height of 7cm.

Nine litter traps of 1 X 5 m were laid down randomly throughout the sampling area. The litter traps were made by enclosing the area with nylon thread. Fallen litters were harvested completely at monthly intervals. Harvested material was brought to the laboratory, separated into leaf and twig components and dried to constant weight at 80°C.

Results and discussion

Monthly litter fall (Table-1) exhibited a bimodal pattern with a maximum in winter and another peak in late summer. A similar pattern was observed by Fu Maoyi *et al.* (1988) in stands of *Phyllostachys pubescens* in South China. Seasonal variation in monthly litter production is given in Table-2. Leaf fall occurred through the year with maximum during December (1556 kg ha^{-1}) and May (1138 kg ha^{-1}), and minimum during March (665 kg ha^{-1}). Rao and Ramakrishnan (1988) observed that maximum leaf fall in two bamboo species (*Neohouzeaua dullooa* and *Dendrocalamus hamiltonii*) occurred during November-January. Lower winter temperature and drier condition may explain the greater leaf fall during the winter months (Longman and Jenik 1974).

Bray and Gorham (1964) reported that *Eucalyptus regnans* pole forest produced a total litter of 6900 kg ha^{-1} of which leaf litter contributed 3600 kg ha^{-1} (50%) and non leaf-litter 3300 kg ha^{-1} (50%). Similarly *E. marginata* virgin forest and *E. marginata* pole forest produced total litter of 2400 kg ha^{-1}. and 3100 kg ha^{-1} respectively. The leaf litter and non leaf litter contributed for the two forests were 1200 kg ha^{-1} (50%) and 1200 kg ha^{-1} (50%) and 2000 kg ha^{-1} (65%) and 100 kg ha^{-1} (35%). On comparing with those studies, the present investigation reveals that *Bambusa bambos* produced more litter when compared with other species. This may be due to the fastgrowing nature of bamboo (Penfold and Willin 1961). With regard to the percentage contribution of litter components (leaf litter 58%, twig litter 42%) the results obtained in the present study are almost comparable with that of Bray and Gorham (1964). However, the results from the rain forest

in K nataka (Rai and Proctor 1986), *Populus deltiodes* from Dehra Dun (Raizada and Srivastava 1986) and moist decidous forest of Coimbatore forest division (Singh *et al.* 1989) showed that, leaf-litter contributed 76-92% of the total litter production. These values are 18 to 34% higher than that of the present study, which may be due to on various factors like nature of species, (evergreen / moist / dry), nature of leaves etc.

Twig litter fall was greatest in November (666 kg ha^{-1}) and lowest in October (548 kg ha^{-1}). Total leaf litter was 10307 kg ha^{-1} and twig litter was7373 kg ha^{-1}. In this study most of the variation in annual litter fall is due to variation in the leaf component. Twig litter fall is relatively constant. (Table-2).

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Table 1. Amount of litter production on average monthly basis (kg/ha)

Months	Leaf-litter	Twig-litter	Total
January	123.6 ± 36.3	90.7 ± 11.7	214.3
February	104.7 ± 13.9	86.3 ± 11.9	191.0
March	93.7 ± 11.2	91.3 ± 6.9	185.0
April	99.1 ± 33.6	78.6 ± 15.5	177.7
May	162.5 ± 72.4	94.0 ± 7.4	256.5
June	139.1 ± 54.4	90.3 ± 5.6	229.4
July	99.6 ± 43.9	78.9 ± 12.5	178.5
August	100.9 ± 14.1	91.8 ± 10.3	192.7
September	103.5 ± 36.9	83.1 ± 8.6	186.6
October	95.9 ± 6.8	78.3 ± 27.0	174.2
November	127.6 ± 26.8	95.1 ± 4.9	222.7
December	223.8 ± 20.80	94.8 ± 8.5	318.6
	1474.0	1053.2	2527.2

Table 2. Litter production (kg/ha) on unit area basis

Months	Leaf-litter	Twig-litter	Total
January	865.00 ± 40.5	635.0 ± 15.0	1500.0
February	733.0 ± 28.3	604.0 ± 13.0	1337.0
March	655.0 ± 27.5	639.0 ± 11.5	1294.0
April	694.0 ± 41.8	550.0 ± 19.5	1244.0
May	1138.00 ± 30.5	658.0 ± 9.5	1796.0
June	974.0 ± 15.5	552.0 ± 3.5	1607.0
July	697.0 ± 35.5	78.9 ± 16.0	1249.0
August	706.0 ± 20.5	643.0 ± 19.2	1349.0
September	725.0 ± 30.5	582.0 ± 30.2	1307.0
October	671.0 ± 41.2	548.0 ± 10.5	1219.0
November	893.0 ± 38.0	666.0 ± 18.4	1559.0
December	1556.0 ± 42.5	664.0 ± 21.5	2220.0
	10307.0	7373.0.	17680.0

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Reprints From Van Vigyan

Chemical Changes in the Leaf Litter of Bamboo (*Bambusa bambos*) During Decomposition

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Abstract : The changes in N, P, K, Ca and Mg from decomposing leaf litter of *Bambusa bambos* were investigated from January 1993 to December 1993. Nutrient release differed from element to element and took place after an initial accumulation stage. Nutrient release was found in the order of K, Ca, Mg, N, P. During the period of one year 55% of N, 20% of P, 79% K, 67% of both Ca and Mg were released.

Key words : *Chemical changes, Leaf litter, Decomposition.*

Introduction : With an increasing interest in the plantation forestry for bridging the gap between the damand and supply, more and more land erstwhile not under forests has been brought under plantations. In order to understand the functioning of such ecosystems, detailed studies on nutrient cycling are of paramount importance. These studies can be utilized preferably for a better management of forest plantations and also to predict the effect of such land use systems on soil environment. Numerous studies on nutrient cycling have been carried out in different countries, but these studies are lacking in the plantations of bamboo. These studies are important for predicting the site degradation, as a result of planting and harvesting and provide a basis for appraisal of nutrient flow within the ecosystem.

This communication deals with the changes in the levels of nitrogen, phosphorus, potassium, calcium and magnesium during the leaf litter decomposition of *Bambusa bambos*.

Material and Methods : The freshly fallen and senescent leaves of *Bambusa bambos* were collected and bagged at the rate of 50 g per polythene bag (with 5 mm mesh size hole). 50 bags of litter was kept on the soil surface by removing one inch surface soil. All such litter bags were covered with freshly fallen and senescent leaves of the same plant. Sampling was done every month for a period of one year.

The bags were removed at the end of every month and brought to the laboratory to determine nutrient contents. Nitrogen and phosphorus levels of the decomposing litter samples were analysed [1] using Technician Auteanalyzer-II. potassium, calcium and magnesium were analysed using an atomic absorption spectrophotometer [6].

Results and discussion

Nutrient Concentration Litter : The concentration of nutrients in the leaf

litter was found in the decreasing order of N followed by K, Mg, Ca and P, during initial stage of the experiment.

Dynamics of Nutrient Element During Decomposition of Bamboo Leaf Litter : The process of decomposition is extremely complex and is controlled by a multitude of organisms (identification was not done) the chemical and physical properties of litter and by the abiotic environment. The temperature and high moisture content conditions could have favoured the high decomposition rate.

The annual release of nutrients during decomposition are presented in Table 1. From the Table it is evident that the concentration of element gradually decreased along with decomposition period. With regard to nutrients release in the decomposed litter, in the decreasing order was found among potassium, calcium, magnesium, nitrogen and phosphorus. It has also been observed that the nutrient content except potassium in decomposing litter was generally higher as compared to the top layer litter. The higher concentration of these nutrients in the decomposing layer is obviously due to the combined effect of leaching from top layer and microbial activities. On the other hand, the low concentration of potassium in the decomposed litter is presumably due to the fast circulation of this element in case of bamboos [11]. It is also expected that leachable nutrients will further get accumulated in the soil strata [8].

It was already known that the decomposition of bamboo leaf litter includes three stages of leaching, accumulation and release [5]. In the present study N, P have long retention, while K, Ca, Mg, are released eesily. Temperature, and precipitation significantly affect the decomposition of bamboo leaf-litter since they influence the level of the microbial population [4]. During the study period, 55% of N, 20% of P, 79% of K, 67% of both Ca and Mg were released.

Table 1. Release of nutrients during decomposition.

Month	Nutrient (%)				
	N	P	K	Ca	Mg
January	0.95	0.10	0.60	0.45	0.49
February	0.92	0.10	0.58	0.43	0.48
March	0.90	0.10	0.57	0.42	0.47
April	0.88	0.10	0.54	0.41	0.45
May	0.82	0.09	0.50	0.33	0.42
June	0.78	0.09	0.45	0.30	0.40
July	0.72	0.09	0.38	0.27	0.38
August	0.67	0.08	0.31	0.24	0.30
September	0.58	0.08	0.26	0.20	0.26
October	0.49	0.08	0.20	0.18	0.20
November	0.45	0.08	0.17	0.16	0.18
December	0.43	0.08	0.13	0.15	0.16

Some workers have reported that most of the elements get leached out during decomposition is in confirmation with the present study [2,3,7]. However, few workers had observed that elemental concentration increased during decomposition [9, 10, 12].

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Litter Production and Nutrient Return in *Bambusa bambos* Plantation

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ABSTRACT. From January 1992 to December 1994 we investigated the litter production and nutrient cycling behavior of *Bambusa bambos* plantations of different ages. The annual litter production was 15.4 t ha^{-1}, 17 t ha^{-1}, and 20.3 t ha^{-1} in 4-, 5- and 6-year-old plantations. Litter production was significantly higher compared to other plantations of similar age. Litter fall had a bimodel pattern with a principal peak in the winter and another in the late summer in all ages. Of the total annual litter production, leaf-litter accounted for 58% and twig-litter 42%. With regards to nutrients, the highest concentration of N, P, Ca and Mg was in leaf litter. On an annual basis, 120, 10, 101, 60 and 66 kg/ha (4 year), 141, 13, 121, 72 and 79 kg/ha (5 year) and 184, 16, 183, 91 and 96 kg/ha (6 year) of N, P, K, Ca and Mg were returned through litter fall. The maximum amount of all nutrients was returned through leaf-litter and lowest amount through twig-litter. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: <getinfo@haworthpressinc.com> Website: <http://www.haworthpressinc.com>]*

KEYWORDS. Litter, *Bambusa bambos*, nutrient cycling, bamboo plantations

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INTRODUCTION

Bamboo is integral to the culture of South and South-East Asia. India has perhaps the world's richest bamboo resources with about 130 species occurring over an area of 10.05 million hectares, about 12.8 percent of the total forest area of the country. The bamboo resources in their natural habitat are dwindling due to over exploitation, gregarious flowering, shifting cultivation practices and extensive forest fires (Tewari, 1992). A sustained production can be ensured only by extensive bamboo cultivation (Shanmughavel and Francis, 1996). The marginal lands, areas not used for raising agriculture crops can be brought under bamboo cultivation, in order to neutralize the rapidly widening mismatch between demand and supply of bamboo resources (Swaminathan, 1980) and maintain an agro-ecological system. Besides these benefits, tree plantations are universally known to result in many positive interactions with the surroundings in which they grow. The soil is influenced greatly by the tree plantations in many ways especially the production of litter and nutrient cycling. Litter enriches the soil with organic matter and essential nutrients. Its accumulation on the surface also check weeds, protects the soil from the erosive impact of rain and reduces surface water run-off (Srivastava et al., 1992).

Few investigations of litter production and the amount of important nutrients recycled through the litter in natural and plantation bamboos exist-nutrient cycling of bamboo in natural forests (Seth et al. 1963), bamboo in slash and burn agriculture (Toky and Ramakrishnan 1983), bamboo in successional environments (Rao and Ramakrishnan 1988), bamboo leaf litter decomposition (Fu et al. 1992), bamboo in dry tropics (Tripathi and Singh 1994), plantation bamboo (Shanmughavel and Francis 1995), nutrient cycling of bamboo planted with teak (Chandrasekara 1996), nutrient cycling in Javanese bamboo talun-kebun system (Mailley et al. 1997)-compared to those for tropical (Rogers and Westmann 1979, Cromer et al. 1982) and temperate (Bray and Gorham 1964) tree species. The difference in climate and the nature and growth patterns of tropical and sub-tropical tree species interalia require carrying out such ecologically important studies. Therefore an investigation was conducted to assess litter production and nutrient recycling characteristics in plantations of *Bambusa bambos* (L.) Voss in India.

MATERIALS AND METHODS

Study Area

The study covered plantations of *Bambusa bambos* located at Kallipatty, Tamil Nadu State between latitude 11° 28′ and 12°E and between longitude 76° 59′ and 77° 47′ N at an altitude of 540 m above mean sea level. This area soil was laterite, red to brown color and andy loam in texture (USDA 1975). Prior to bamboo planting, paddy, maize and tobacco are cultivated in field. The soil moisture content was determined by drying 10 g fresh soil in a hot-air oven at 150°C for 24 h. The pH (7.4 -7.8) was measured on an electric digital pH-meter in a 1.5 (w:v) soil water suspension. For N, P and K, the samples were air dried and sieved (0.2 mm). Total N was estimated by the indophenol blue method described by Allen (1974). Potassium was extracted from the soil in an ammonium acetate solution (pH = 7) and was measured with a digital flame photometer (Systronics-121, India). To obtain the total soil nutrient concentrations per hectare, the percentage nutrient content was divided by 100 and the result multiplied by 2 million. One hectare usually contains ca. 2×10^6 kg soil (George and Varghese 1990). The maximum soil nitrogen, phosphorus, potassium, calcium and magnesium are 3800, 360, 3600, 1600 and 1800 kg ha^{-1}, respectively. The mean temperature is 31°C and the mean annual rainfall about 600 mm.

Plantation Details

The sampling area (3 hectare) was a pure bamboo plantation stands (*Bambusa bambos*). Density was 3500, 4000 and 4250 culms/ha in 4th, 5th and 6th years, respectively. The mean culm height was 21.8, 27.2 and 28.5 m during 4th, 5th, and 6th years. Their corresponding mean diameters at breast height (DBH) at different ages were 4.8, 6.3, and 8.3 cm, respectively.

Litter Determination

Measurements of litter production were conducted from January 1992 to December 1994. Average periodic litter-production measurements were made using 9 wooden traps. These traps were randomly

located in plantations to represent an average of the total area. Each trap was 1 m^2 and 20 cm depth to allow accumulation of falling litter. These traps were designed such that litter would be retained in the containers once it is trapped and the litter within (or) outside the trap would not get intermixed either by the wind (or) small animals (or) undergo loss from decay due to collection of water within them. The traps were fixed about 15-20 cm above ground level by pegs at the corners. The litter collected in each of the traps was removed at monthly intervals, except during rainy season when weekly collections were made. Periodically collected litter was brought to the laboratory, separated into leaf and twig components and oven-drying at 80°C to a constant weight (Fu et al. 1983).

Nutrientent Analysis

A composite litter sample was also taken for the chemical analysis. The oven-dried litter samples were washed with acidulated (0.05 M NH_4Cl) water followed by distilled and deionized waters. The samples were ground to pass through a 0.5 mm stainless steel sieve before digestion.

Nitrogen and Phosphorus

Nitrogen and phosphorus were estimated (Armstrong et al. 1997) using a Technicon Auto analyzer II (Gedko International Ltd., UK). The sample was digested in a Kjeldahl digestion system KT 408 (Bonn) at 400°C for 3 hours. One gram sample was digested with 2.5 g K_2SO_4 and 5 ml H_2SO_4 made upto 50 ml with distilled water and used for analysis of nitrogen and phosphorus.

Potassium, Calcium and Magnesium

The nutrients K, Ca, and Mg were analyzed using an Atomic Absorption Spectrophotometer (Perkin Elmer 5000, USA) after wet digestion of one gram sample with triple acid mixture (10 ml of conc. HNO_3, 4 ml of $HClO_4$ and 1 ml of conc. HCl). The digested samples were filtered through Whatmann No. 42 filter paper and made up to 100 ml with distilled water. This solution was stored and used for analysis (Issac and Johnson 1975).

RESULTS

Litter Production per Unit Area

Annual litter production in bamboo increased with successive years (Table 1). Total leaf-litter was 9200 kg-ha^{-1} (4th year), 10,307 kg-ha^{-1} (5th year) and 11,833 kg-ha^{-1} (6th year) and twig-litter was 6200 kg-ha^{-1} (4th year), 7373 kg-ha^{-1} (5th year) and 8473 kg-ha^{-1} (6th year). The annual litter production was 15.4 t.ha^{-1} (4th year), 17.6 t.ha^{-1} (5th year) and 20.3 t.ha^{-1} (6th year).

Seasonal Fluctuations in Litter Fall

Monthly litter fall in bamboo plantation indicated a bimodel pattern with a principal peak in the winter season (November-February) and another in the late summer (May-June) in all ages of plantation. Winter peak (November-February) returns more litter (3640 kg/ha), whereas summer peak (May-June) returns less litter (2005 kg/ha). The litter fall in winter accounted for a major fraction of the annual litter yield in all ages of plantation. Approximately 40% of the annual litter production was obtained during winter season.

Nutrient Concentration of Litter

Since there was not much variability in the nutrient concentration of litter components during different months of the year, the average values were taken into consideration for further investigation. The average nutrient concentrations of litter components of bamboo for all age groups were presented in Table 2. The relative amounts of nutrient elements were found in the order of N, K, Mg, Ca, P in leaf, whereas in twig they are in the order of K, N, Mg, Ca, P.

Nutrient Return

The comparative amounts of N, P, K, Ca and Mg recycled through the litter of 6th year were found to be higher than the corresponding quantities through 4th and 5th year plantation (Table 3). The maximum nutrient return was through leaf-litter (60%) and the rest by twigs (40%) in all age groups of bamboo. Table 4 shows the annual release of nutrients through litter fall in different forest ecosystems, including results from the present study as a comparison.

TABLE 1. Litter Production (kg/ha) on Unit Area Basis in *Bambusa* Plantations

LITTER COMPONENTS

MONTHS	4th YEAR			5th YEAR			6th YEAR		
	LEAF	TWIG	TOTAL	LEAF	TWIG	TOTAL	LEAF	TWIG	TOTAL
Jan.	730 ± 10.5	540 ± 7.5	1270	865 ± 40.5	635 ± 15.0	1500	982 ± 45.0	759 ± 15.0	1741
Feb.	650 ± 11.5	510 ± 10.5	1160	733 ± 28.3	604 ± 13.0	1337	817 ± 30.5	668 ± 13.0	1485
Mar.	560 ± 9.0	530 ± 8.0	1090	655 ± 27.6	639 ± 11.6	1294	710 ± 31.0	693 ± 13.5	1403
Apr.	580 ± 8.5	460 ± 10.5	1040	694 ± 41.8	550 ± 19.5	1244	784 ± 45.8	619 ± 17.0	1403
May	1080 ± 10.7	570 ± 7.4	1650	1138 ± 30.5	658 ± 9.5	1796	1320 ± 33.5	767 ± 9.5	2087
Jun.	925 ± 9.5	540 ± 6.8	1465	974 ± 15.5	632 ± 13.5	1607	1106 ± 18.5	718 ± 10.0	1824
Jul.	575 ± 15.5	460 ± 8.5	1035	697 ± 15.5	552 ± 16.0	1249	809 ± 40.5	635 ± 19.5	1444
Aug.	590 ± 13.5	530 ± 7.6	1120	706 ± 20.5	643 ± 19.2	1349	833 ± 20.5	767 ± 13.0	1600
Sep.	665 ± 14.0	485 ± 9.5	1150	725 ± 30.5	822 ± 30.2	1307	875 ± 25.0	677 ± 14.0	1552
Oct.	585 ± 11.5	450 ± 11.5	1035	671 ± 41.5	548 ± 10.5	1219	759 ± 30.5	627 ± 10.5	1386
Nov.	795 ± 10.5	665 ± 9.0	1060	893 ± 38.9	666 ± 18.4	1559	1023 ± 21.5	776 ± 20.5	1799
Dec.	1465 ± 16.5	560 ± 6.5	2025	1556 ± 42.5	664 ± 21.5	2220	1815 ± 25.0	767 ± 21.0	2582
TOTAL	9200	6200	15400	10307.0	7373.0	17680.0	11833	8473	20306

The annual litter production was estimated in the field by laying nine litter plots. The falling litter was collected at every month for a period of one year. Fresh weights were taken in the field and sub-samples in triplicate was brought to the laboratory and oven dried at 80°C. A bimodel pattern of litter production was noticed with principal peak during December and another one during May. The leaf litter found to be higher than twig litter.

TABLE 2. Nutrient Concentration in Litter Components (mg g^{-1})

LITTER COMPONENTS						
	4th YEAR		5th YEAR		6th YEAR	
NUTRIENTS	LEAF	TWIG	LEAF	TWIG	LEAF	TWIG
N	9.1 ± 5.0	5.8 ± 4.2	9.4 ± 2.0	6.1 ± 5.9	9.7 ± 5.4	8.2 ± 5.4
P	0.8 ± 0.5	0.5 ± 4.0	0.9 ± 0.5	0.6 ± 0.1	0.8 ± 0.0	0.8 ± 0.5
K	6.3 ± 5.0	7.0 ± 5.4	6.5 ± 1.0	7.3 ± 5.4	9.3 ± 2.7	8.6 ± 1.0
Ca	4.5 ± 7.0	3.1 ± 5.1	4.7 ± 5.0	3.3 ± 4.9	4.8 ± 2.4	4.0 ± 3.9
Mg	4.7 ± 5.0	3.7 ± 4.1	4.9 ± 5.4	3.9 ± 5.1	5.1 ± 3.0	4.3 ± 1.0

Results are average of three independent observations. Since there was little difference between observations, average values are given. The nutrients were found in the order of N > P > Mg > Ca > P in leaf whereas in twig K > N > Mg > Ca > P.

TABLE 3. Nutrients Return Through Litter Fall (kg/ha)

LITTER COMPONENTS									
	4th YEAR			5th YEAR			6th YEAR		
NUTRIENTS	LEAF	TWIG	TOTAL	LEAF	TWIG	TOTAL	LEAF	TWIG	TOTAL
N	84	36	120	96	45	141	115	69	184
P	7	3	10	9	4	13	9	7	16
K	58	43	101	67	54	121	110	73	183
Ca	41	19	60	48	24	72	57	34	91
Mg	43	23	66	50	29	79	60	36	96

Results are the average of three independent observations. Since there was litter difference between observations, average values are given. The maximum nutrients return was through leaf litter (60%) and the rest by twigs (40%).

DISCUSSION

Amount of total litter fall (leaves and twigs) in the present study was estimated around 17.8 Mg ha^{-1} $Year^{-1}$ which is 6 fold higher than above ground litter production in *Dendrocalamus strictus* plantation (3.2 Mg ha^{-1}) in India (Seth et al. 1964). Christanty et al. (1996) reported above ground litter fall in 6 year old *Gigantichloa* spp. around 4.7 Mg ha^{-1} $Year^{-1}$. Rozanov and Rozanova (1964) reported values for total above ground litter fall for bamboo plantations as 6.6 Mg ha^{-1} $Year^{-1}$ under thinned tropical forest and 10.6 Mg ha^{-1} $Year^{-1}$ under thinned monsoonal forest which are 2.7 and 1.7 fold lower than in the present study. In addition, the litter fall production of 4.2 to 7.2 Mg ha^{-1} $Year^{-1}$ for mature bamboo in dry tropical savannas is 4.2 to 2.5 fold lower compared to the present study (Tripathi and Singh 1994). The values of the present study are also 4.2 to 28.3 fold higher and 2.7 to 17.4 fold higher than those observed for 15 and 20

TABLE 4. Annual Release of Nutrients (kg/ha^{-1}/yr) Through Litter Fall in Different Forest Ecosystems

Forest type & Locality	Nitrogen	Potassium	Phosphorus	Calcium	Magnesium	Source
Spruce (USSR)	52	12	2	48		Soon, 1960
Birch (USSR)	66	13	5	54		Smirnova and Corodentseva 1958
Oak (USSR)	59	62	3	86		Mina, 1955
Eucalyptus tereticornis	14.2-34.5	–	8.6-20.8	98.2-334.5		Singh, 1984
(U.P. India)	82	19	11	131		Seth et al.
Tectona grandis	46	19	9	77		1963
(U.P. India)	73	39	13	46		-do-
Shorea robusta	18	6	0.3	5		-do-
(U.P. India)	46.53	13.61	10.21	56.17		Singh,
Pinus spp. (U.P. India)	47.78	16.86	28.81	70.97		K.P. 1968
Butea spp. (U.P. India)	40.69	9.0	15.16	52.78		Seth et al.
Piecea smithiana	24.45	6.03	7.93	34.93		1963
(H.P. India)						-do-
Cedrus deodara						-do-
(H.P. India)	120.0	101.0	10.0	60.0	66.0	-do-
Abies bindrow						
(H.P. India)	141.0	121.0	13.0	72.0	79.9	
Pinus wellichiana						
(H.P. India)	184.0	183.0	16.0	91.0	96.0	
Bambusa bambos plantation						
(India) 4 year	120	101	10	60	66	Present study
5 year	141	121	13	72	79	Present study
6 year	184	183	16	91	96	Present study

year bamboo growing in teak plantations. This may be due to the fast growing nature of *Bambusa bambos* compared to other bamboo species and confirms the statement of Penfold and Willin (1961) that, the faster a species grows, the more litter it would produce. The regular increase in the litter yield with increase in age found in this study shows continual development of the canopy, which conforms to what is normally expected in young plantations.

Seasonal changes in litter-fall indicate that the winter season accounts for the most annual litter production. This is unlike deciduous plantations (Seth et al. 1964) and *Gigantichola* (Mailly et al. 1997) where maximum litter yields were during the summer months. Litter fall within a year exhibited a bimodel pattern with a principal accumulation peak in the winter and another in the late summer, in all ages of plantations. Similar types of two annual peaks in stands of *Phyllostachys pubescens* were observed by Fu et al. (1988). Leaf fall occurred throughout the year with maximum during December and May, minimum during March in all ages, whereas the maximum leaf fall in other

bamboo species *Neohouzeua dulloa* and *Dendrocalamus hamiltonii* occurred during November-January (Rao and Ramakrishnan 1988). Ghristanty et al. (1996) observed maximum leaf fall during September and October in *Gigantichola* spp. Lower temperature conditions of the winter and dryness of the season (Longman and Jenik 1974) may be contributing factors for greater leaf fall during the winter.

The percentage contribution of litter components, observed in the present study, is comparable with that of Bray and Gorham (1964). Branch litter fall equaled 40.26%, 41.70% and 41.73% of the total litter fall during 4th, 5th and 6th year respectively. This is higher compared to 25% in *Dendrocalamus strictus* (Seth et al. 1963) and *Gigantichola* spp. (Christanty et al., 1996). The leaf-litter contributed 60% and twig-litter 40% at 4th year, whereas in 5th and 6th years, the leaf-litter contributed 58% and twig-litter 42%. This variation in litter production coincides with variation in the climate of the locality and growing season of the species (Longman and Jenik 1974). In deciduous plantations, the contribution of leaf litter to the total litter was 76-92%, which is comparatively much higher than bamboo plantations, which may be due to the fact that the leaf-litter depends on various factors like nature of species (evergreen/moist/dry), nature of leaves, etc. (George, 1977).

Composition of the litter is regarded as a measure of the intrinsic quality (decomposability) and environmental characteristics of the soil and climate which, in turn, affect the release of the important nutrient elements through decomposition. The nutrient concentration of N, P, K, Ca and Mg in the litter of bamboo increased with age (Table 2). The highest concentration of different nutrients in the various living biomass components was generally observed in leaf, branch, culm and rhizome. The proportion of nutrient elements were in the order of K, N, Mg, Ca and P except for leaves, where the nutrient elements were found in the order of N, K, Mg, Ca, P. The nutrient concentration in different litter components was lower than the living biomass. This may be partly due to translocation and withdrawal of appreciable quantities of nutrients before abscission (Kramer and Kozlowski 1960, Grubb and Edwards, 1988). In addition some of the elements may be leached out before litter fall. In bamboo, potassium, which is more readily leachable (Nye and Greenland 1960), was lower in the litter than in the living biomass. The return of elements to the soil through litter fall increased with age in the present study. This is a

function of the increase in litter fall with age (Rao and Ramakrishnan 1988).

The highest concentration of N, P, Ca and Mg was observed in leaves, while twigs had the highest concentration of K in all ages. In leaves, among the various nutrients N had the maximum percentage followed by K, Ca, Mg and P. These results are in general agreement with those observed in *Eucalyptus globulus* (Venkataraman et al. 1983), *E. hybrid* (George 1977) and *E. globulus* (George and Varghese 1990). The elemental concentration in twig decreased in the order of K, N, Mg, Ca and P.

The maximum amount of all nutrients was returned through leaf litter and minimum by twig litter. Twigs contributed 30 to 39% of all nutrients. Similar results were observed in different forest tree species (Srivastava et al. 1972, George and Varghese 1990). The results of the present study indicate that, *Bambusa bambos* returns substantial quantities of N, K, Ca, Mg and P through litter fall. The twig-litter is collected for various other uses and therefore great drain of nutrients takes place. The results also point to the necessity of precautionary measures to maintain the nutrient status of the soil in these plantations.

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TREND OF VARIATION IN FIBRE-LENGTH IN AN AGE SERIES OF BAMBUSA BAMBOS

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ABSTRACT : Fibre analysis and Fibre classification experiments were conducted on *Bambusa bambos* plantations of ages ranging from 1 to 6 years. No appreciable change in fibre length and percentage content of +50, +65, +100 and -100 mesh fibres in both unbleached pulp and bleached pulp could be monitored with increasing age. The result indicate that probably these bamboo species attain their maturity during the first year of growth. For pulping purposes, these species seem to be suitable for a one year old cutting cycle.

Key words : *Fibre length, Fibre classification, Bambusa bambos*

INTRODUCTION

Physical properties like specific gravity and fibre morphology and chemical properties of lignocellulosic materials are of considerable importance especially in determining their end use. Fibre dimensions such as fibre length influence the physical and mechanical properties which in turn affect the work-ability (Paramasivam & Liese 1976), Espiloy 1987, Abd. Latif et al. 1990, Abd. Latif et al. 1991, and Jamaludin & Abd. Latif 1993). Fibres are the important parts of the raw materials in the paper and pulp industry. Fibre length is an important criterion in identifying the fitness of the wood for pulping as it has direct correlation with the tearing strength of the paper. (Bublitz 1980) Fibre length also influences the drainage capacity of the pulp. Variability between different kinds of plant species is due to the differences in their anatomical and chemical properties. Even though the patterns of variation in fibre elements, physical and chemical properties of normal trees grown under forest conditions are fairly, well established (Razzague et al. 1981, Abd. Latif and Mohd. Mustafa 1992, Jamaludin & Abd. Latif 1993) they are hardly applicable to plantation bamboos. This paper attempts to discuss the trend of variation in fibre length and fibre classification (+05, +65, +100, and -100 mesh fibres) in an age series of *Bambusa bambos* plantation.

MATERIAL AND METHODS

To study the pulp and paper characteristics in an age series of *Bambusa bambos*, screened chips were collected from summer chipper. They were pulped in the Laboratory series digester with different percentage of alkali at 172° C for 60 minutes to get a target kappa number of 27 ± 2. The sulphidity in white liquor was 18 ± 0.5%. The dilution was kept at 1:3. The H factor was maintained at 1300. The pulp obtained was washed thoroughly. The knots were hand picked. Percentage of pulp yield and knots were determined. The pulp was tested for koppa number, SR, fibre fraction, brightness and blackability. Fibre length and fibre classification were evaluated from both unbleached pulp and bleached pulp. (Seshashayee Paper Board 1986).

RESULTS AND DISCUSSION

The fibre make up the sclerenchymatous tissue and occur as caps of vascular bundles or isolated strands. They are long and tapered at both ends. Good tear, burst, tensile and folding endurance values are the requisites of a good paper. These values vary with the fibre length and diameter as well as with the ratio of these two. It is interesting to note that, no appreciable change could be monitored with increasing age (Table 1). The fibre length obtained in this study ranges between 2mm to 2.5 mm in first and sixth year old *Bambusa bambos*. It indicates that fibre length very slowly increases with age. The results supports the findings of Razzaque et al. (1981) Jamaludin & Abd. Latif (1993). However, Abd. Latif and Mohd. Mustafa (1992) reported that the fibre length of both *B. vulgaris* and *G. scortechinii* generally increases with age, that in *B. blumeana* decreases. The result indicate that, probably these bamboo species attain their maturity during the first year of growth. As mentioned by many researchers, the fibre length within and between the bamboo culm may vary as the individual characteristics of the bamboo itself. (Grosser & Liese 1971, Pattanath 1972, Espiloy 1987, Widjaja and Risyad 1987).

The fibre classification of both unbleached pulp and bleached pulp were presented in Table 2 & 3. Similar to fibre length, the percentage content of +50, +65, +100 and -100 mesh fibre does not show much variation in both unbleached and bleached pulp. The life history of the bamboo culms should account for some of the variations. It is conceivable that, external factors such as soil conditions and climatic changes during fibre development might influence fibre length.

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Table-1 : Fibre Length in *Bambusa Bambos*

Fibre classification	Years					
	1	2	3	4	5	6
Bamboo Density (gm/cc)	0.588	0.593	0.598	0.610	0.617	0.622
Average fibre length (mm)	2.0	2.0	2.3	2.3	2.5	2.5
Chips density (BD) kg/m^3	200.41	202.10	208.10	215.00	220.10	224.76

Table-2 : Unbleached Pulp Fibre Classification

Fibre classification	Years					
	1	2	3	4	5	6
+ 50 mesh fibre (%)	68.10	68.90	69.10	69.80	69.96	69.96
+ 65 mesh fibre (%)	7.44	8.10	8.42	8.92	8.92	8.92
+ 100 mesh fibre (%)	3.72	3.74	3.80	3.83	3.83	3.83
- 100 mesh fibre (%)	18.88	18.96	19.00	19.09	19.09	19.10

Table-3 : Bleached Pulp Fibre Classification

Fibre classification	Years					
	1	2	3	4	5	6
+ 50 mesh fibre (%)	76.10	78.20	79.12	80.27	80.40	80.70
+ 65 mesh fibre (%)	9.39	9.42	9.63	9.70	9.89	9.90
+ 100 mesh fibre (%)	5.10	5.24	5.40	5.42	5.50	5.51
- 100 mesh fibre (%)	4.39	4.53	4.62	5.00	5.10	5.10

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STUDIES ON COMPARISON OF PULP AND PAPER MAKING CHARACTERISTICS OF PLANTATION BAMBOO WITH SOME TREE SPECIES

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ABSTRACT : The supply of traditional bamboo species has been dwindling in the recent years. With the gradual shortage of such raw material the pulp industries are forced to look for alternative stock. Sustained availability can be ensured only by raising eleborate bamboo plantations. An attempt has been made to compare the pulp and paper making characteristics of plantation bamboo (*Bambusa Bambos*) with *Eucalyptus tereticornis, Acacia decurrens, Acacia arabica* and *Erythrina suberosa*. The result showed, that pulp from bamboo has better properties than other tree species. However, comparing the strength properties of pulp from other tree species next to plantation bamboo, *Eucalyptus tereticornis, Acacia arabica* seems to have potential as a moderate material for pulping among the hardwoods.

Keywords : Pulp and paper characteristics, plantation bamboo, *Eucalyptus tereticornis, Acacia decurrens, Acacia arabica, Erythring suberosa.*

INTRODUCTION

During the last few decades, bamboo has become a major source of raw material for the Indian pulp and paper industry. The industry is presently facing problems of nonavailability of suitable fibrous raw materials in adequate quantity to meet its requirements. The supply of traditional bamboo species for pulp making has been dwindling in the recent years. Still bamboo accounts for about 60 percent of the fibrous raw material requirements of the Industry. With the gradual shortageof such raw materials, the pulp industries are forced to look for alternative stock. (Shanmughavel and Francis 1995). The present study is, therefore aimed to investigate the suitability of plantation bamboo for pulping in comparison with Eucalyptus hybrid (*Eucalyptus tereticornis*), Wattle (*Acacia decurrens*) Dadup (*Erythrina suberosa*) and Karuvelan (*Acacia arabica*).

MATERIALS AND METHODS

To study the pulp and paper characteristics, screened chips [Chips density (BD) - 224.76 kg (m^3) were collected from sumner chipper in case of plantation bamboo, and screened chips [Chips density (BD) 254.60 kg/m^3 for Eucalyptus hybrid, 265 kg/m^3 for wattle, 267.46 kg/m^3 for Karuvelan, 162.56 kg/m for Dadup] were collected from KMWHH 300 chipper. They were pulped individually in the laboratory series digester heated with indirect steam. The digester was initially heated to a temperature of 80°C and then oven dried chips equivalent to 2000 g were charged

with chemicals in all the cooks. For bamboo and hardwoods cooking were done at two different H - factor to get two values of kappa number. The other cooking conditions were maintained at 19% to 22% active alkali (as Na20), 25% sulphidity, 1:3 liquor to wood ratio and 90 min to raise the temperature to 170 C.

After cooking, the chips were discharged, thoroughly washed, disintegrated and then screened. The screened pulps were pressed to remove excess water, shredded, weighted and then sampled for determining moisture content. The screening rejects were also oven dried. The pulp yield and screened pulp kappa number were determined. Physical strength properties were studied in the unbleached pulp. The bleaching experiments were carried out for all the pulps using CEH sequence. (Chlorination, alkaline extroction, hyphochlorite). The bleached pulp samples were then refined in a valley beater to different freeness values and handsheets were made to determine the strength properties after conditioning the sheets at 23 * 1 C and 50 * 1% relative humidity.

RESULTS AND DISCUSSIONS

The active alkali requirement to obtain the pulp yield is 19% for *Bambusa bambos* and *Eucalyptus tereticornis*, 2% for *Acacia decurrens* and *Erythrina suberosa* and 22% for *Acacia arabica*. The pulp yield in all the species ranges from 43.65% to 54.32% which is comparable with 42-48% of the sulphate process (Chao and Pan 1972) and 45-53% of kraft pulping (Kasim et al. 1992) Good tear burst, tensile, and folding endurance values are the requisites of a good quality paper. (Razzaque et al 1981).

In bamboo, the burst factor, tear factor and breaking length was found to be higher in comparison with othertree species. (Table-1). The pulp properties of other tree species were found in the order of *Eucalyptus hybrid, Acacia arabica, Acacia decurrens* and *Erythrina suberosa:* However, the strength of paper produced from *Acacia decurrens, Acacia arabica* was relatively lower in folding endurance. This reflects the stiffness of fibres (Caesey, 1980) which is due to thicker cell wall. The lower strength properties of other tree species could be related to the full lignification which occurs during the growth. (Kasim et al. 1992). Further more, with increasing tree age, the cell wall is lignified, cellulose structure becomes less exposed and thus hinders the fibre bonding. This leads to comparatively lower strength properties of other tree species.

The results of the present study indicates that, pulp from plantation bamboo has better properties than other tree species. However, comparing the burst and tear strength of the paper produced from *Eucalyptus tereticornis, Acacia arabica* seems to have potential as a moderate material for pulping, among the hardwoods. Hence next to plantation bamboo these two hardwood species can also be used for pulping.

CONCLUSION

The National Commission on Agriculture (1985) has broughout some figures about the current demand and output of wood, the projected requirements for 1980 (219.769 million cum) and 2000 (296.45 million Cum) and recommended the measures required to

Table-1 : Comparison of pulp and paper making characteristics of plantation bamboo with hardwood species

Species	Active alkalias	Pulp yield	Physical strength properties of bleached pulp				Bleacha-bility Test	Pulp yield	Physical strength properties of bleached pulp			
	Na_2O (%)	(%) Unble-ached	Burst factor	Tear factor	Breaking length (km)	Folding endur-ance	Cl_2 Con-sumption (%)	Blea-ched (%)	Burst factor	Tear factor	Breaking length (km)	Folding endura-nce
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Plantation bamboo (*Bambus a bambos*)	19	48.80	44.0	68.9	6.41	140.0	10.49	45.0	40.0	63.8	4.38	122.0
Eucalyptus tereticornis	19	43.65	40.5	56.7	6.20	178.0	9.61	38.5	37.4	51.5	4.89	160.0
Acacia decurrens	20	54.32	33.2	48.3	6.20	130.0	7.51	49.3	30.4	42.3	5.10	110.0
Acacia arabica	22	50.62	38.7	54.5	5.90	160.0	8.08	47.0	33.5	40.5	3.21	140.3
Erythrina suberosa	20	49.65	34.7	47.8	5.90	265.0	10.85	39.3	30.8	41.5	4.20	249.0

The values given above are the results of three independent observations. Since, not much variation in the results was observed, the mean average values were given.

bridge the increasing gap between supply and demand. One such measure is to raise elaborate bamboo plantations and other hardwood species, and to study the pulping characteristics of them. Hence, the present study was carried out. This study indicates that next to plantation bamboo, *Eucalyptus tereticornis, Acacia arabica* can also be used as a substitute for the traditional bamboo resources in the pulp industry.

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NOTE

THE OPTIMUM AGE FOR FELLING OF PLANTATION BAMBOO (*BAMBUSA BAMBOS*) FOR PULP AND PAPERMAKING

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Bamboo is considered to be a unique raw material in terms of its quick growth, early availability, straightness, smoothness, etc. It is used for various purposes such as construction of rural houses, ladders, mats, baskets, pipes, handicrafts, etc. However, the highest demand is for the manufacture of paper. During the last few decades, it has become a major source of raw material for the Indian pulp and paper industry. The paper industry has an installed capacity of 0.3 million tonnes, covering 316 small, medium and big paper mills and produced about 2.75 million tonnes of paper and paper board during the year 1992 (Adkoli 1992).

The industry is currently facing problems of getting suitable fibrous raw materials in adequate quantity to meet its requirements. The supply of bamboo, so far the main raw material for the industry, has been dwindling in recent years. Sustained availability can be ensured only through elaborate cultivation of bamboo (Shanmughavel 1995). However, bamboo only accounts for 60% of the fibrous raw material requirement of the industry. In order to meet the present and future requirements of the paper industry, efforts are needed not only to improve productivity, but also to use the existing bamboo resources judiciously and efficiently. In view of this, an experimental trial of *Bambusa bambos* was conducted at Kallipatty, Tamil Nadu, India.

During the extraction of bamboo from the forest, no definite cutting age was employed. Rather, bamboos of different age groups were extracted indiscriminately. As a result, pulping of a mixture of bamboos of different age groups resulted in heterogenous cooking, producing inferior quality pulp. To overcome this, this study was undertaken to determine the optimum age for felling of bamboo for pulp and papermaking and the optimum cutting cycle for the species. In the literature various workers, e.g. Razzaque *et al.* 1981 (*Melocanna baccifera, Oxytenanthera nigrociliata, Dendrocalamus longispathus, Bambusa tulda* and *Neohouzeaua dulloa*), Bose *et al.* 1988 (*Melocanna baccifera*), Maheswari and Satpathy 1988 (*Dendrocalamus strictus*) and Jamaludin *et al.* 1992 (*Gigantochloa scortechinii*), have already reported the influence of age of bamboo on pulping.

The pulp and papermaking characteristics of one- to six-y-old *Bambusa bambos* have been investigated (Shanmughavel 1995). The salient points are:

- Fibre and pulp qualitative characters are almost equal in all the ages of bamboo (e.g. fibre length, Table 1). Their quantity differences are dependent on the total biomass production, which is related to the age of the plantation, indicating that age is not acriterion for qualitative fibre harvest.
- With an increase in age, cellulose, lignin, pentosans, 1% NaOH solubles, alcohol-benzene solubles, hot water solubles and ash contents also increase (Table 2).
- With increasing age active alkali requirement to obtain a fixed kappa number increases. Total pulp yield also increases with age of culm (Table 3).
- The physical and strength properties of both unbleached (Table 4) and bleached pulps increase with the age of bamboo.

Table 1. Fibre length in *Bambusa bambos*

Property	Age (y)					
	1	2	3	4	5	6
Bamboo density (g cm^{-3})	0.588	0.593	0.598	0.610	0.617	0.622
Average fibre length (mm)	2.0	2.0	2.3	2.3	2.5	2.5
Chips density (BD) (kg m^{-3})	200.41	202.10	208.10	215.00	220.10	224.76

Figures are means of three replicates. There was no significant variation in fibre length.

Table 2. Proximate chemical composition of *Bambusa bambos*

Age (y)	Ash (%)	Hot water solubles (%)	Alcohol-benzene solubles (%)	1% NaOH solubles (%)	Pentosans (%)	Lignin (%)	Cellulose (%)
1	1.20	4.47	7.50	20.50	19.10	28.00	60.01
2	1.50	4.60	7.50	21.90	19.32	28.50	61.20
3	1.70	4.90	7.90	22.50	19.53	29.00	62.50
4	1.90	5.10	8.00	23.00	19.62	30.50	63.30
5	2.10	5.80	8.00	23.00	20.33	31.50	64.50
6	2.30	5.95	8.00	23.50	20.20	32.00	65.60

Figures are means of three replicates.

The study revealed that in the plantation bamboo, although no appreciable change in chemical composition of pulps could be detected with increasing age, the bamboo species reached maturity during the first year of growth. Hence, one- to six-y-old culms can be used as raw material for pulping. However, in order to get a higher annual yield of culms in the subsequent years it is recommended that a 36-month cutting cycle is ideal for pulping purposes.

Bose *et al.* (1988) suggested a cutting cycle of 21 months for muli bamboo (*Melocanna baccifera*) with regards to yield gain. Biennial felling cycle has also been observed to give maximum yield and superior quality in the case of *Dendrocalamus strictus*. From the management point of view, biennial felling cycle does not pose any serious difficulty (Mohan 1931). Chen *et al.* (1985) also concluded from the study on 10 bamboo species, that the bamboos should not be older than 36 months for chemical utilization if practices of cultivation and rotation were considered.

Table 3. Pulping data

Characteristic	Age (y)					
	1	2	3	4	5	6
Total pulp yield (%)	46.36	47.23	48.10	48.30	48.44	48.80
Knots (%)	2.27	2.19	2.24	2.26	2.30	2.30
Kappa number	27.2	27.6	27.6	28.9	28.9	28.9

Table 4. Physical strength properties of unbleached pulp

Characteristic	Age (y)					
	1	2	3	4	5	6
Burst factor	47.8	48.0	48.2	48.9	49.0	49.1
Tear factor	80.0	84.0	84.0	85.0	86.0	86.5
Breaking length (m)	6706	6780	6990	7210	7222	7222
Double folds	85	95	120	150	160	180

Figures are means of three replicates.

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III

Comparison of Fibre-Length of Plantation Grown Bamboos with Natural Stand Bamboos*

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Bamboo is a potential raw material for pulp and paper making due to its long fibres. India perhaps has the world's richest resources of bamboo, claiming about 130species occurring over an area of 9.67 million hectare. This is about 12.8 per cent of the total forest area of the country. However, bamboo resources in their natural habitat is dwindling, due to over exploitation, gregarious flowering, shifting cultivation practices and extensive forest fires. The Development Council for Pulp and Paper, Ministry of Industry appointed a raw material committee for pulp and paper. This committee reported that projected requirements of bamboos was 4.274 million cu m in 1980 and it would be 7.005 million cu m by 2000 and recommended the measures required to bridge the increasing gap between demandand supply. One of the recommendations is the sustained availability of bamboo by raising eleborate bamboo plantations and also to use the existing bamboo resources judiciously and efficiently. Therefore, it is of interest to compare fibre length of plantation grown bamboos with bamboos of natural stands. Hence measurements of the fibre dimensions were made on macerated fibres obtained after treating with Jeffrey's solution (50-50 mixture of 15 % Nitric acid and 10 % Chromic acid) [5].

The comparison of fibre dimensions of various bamboos are presented in Table 1. It indicates that no significant difference in the length of fibre of plantation grown bamboo with its counter parts in natural stands.

The influence of fibre morphology on the physical properties of pulp have been demonstrated by many scientific studies. There are three principal factors affecting the strength properties of pulp (i) fibre density, (ii) fibre length and (iii) fibre strength [3].

Our study revealed that there is considerable difference in fibre-length within one culm. Across the wall, the fibre length often increases from periphery and reaches its maximum at the

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Table 1. Comparison of fibre dimensions in some species of bamboo.

Sl. No.	Name of Species	Fibre length (mm)	Fibre diameter ($\times 10^{-1}$mm)	Wall thickness ($\times 10^{-1}$mm)
A. Natural stand				
1.	*Bambusa bambos*	2.73	0.19	0.06
2.	*Bambusa polymorphs*	3.19	0.18	0.05
3.	*Bambusa tulda*	2.98	0.16	0.04
4.	*Dendrocalamus giganteus*	2.69	0.18	0 05
5.	*Dendrocalamus hamiltonii*	3.36	0.17	0.04
6.	*Dendrocalamus strictus*	3.06	0.18	0.05
7.	*Dendrocalamus longispathus*	3.50	0.19	0.06
8.	*Melocanna baccifera*	2.72	0.16	0.04
9.	*Schizostachyus dullooa*	3.63	0.17	0.05
10.	*Ochlandra travancorica*	4.03	0.18	0.05
11.	*Phyllostachys bambusoides*	1.52	0.19	0 06
B. Plantation stand				
1.	*Gigantochloa scortechnii* (3 year old)	3.77	0.19	0.06
2.	*Bambusa bambos*			
	(1 year old)	2.00	0.16	0.04
	(2 year old)	2.00	0.16	0.04
	(3 year old)	2.30	0.17	0 04
	(4 year old)	2.30	0.17	0.04
	(5 year old)		0.18	0.05
	(6 year old)	2.50	0.18	0.05

middle and decreses towards the inner part, (or) the length may exhibit a general decrease from the outer part to the inside [2]. The fibres in the inner zones of a culm are always much shorter (20 40%). The shorter fibres are always near the nodes; the longest in the middle part. With increasing height of the culm, a slight reduction in fibre length occurs [1].

The maximum (4.03 mm) and minimum (1.52 mm) fibre length was observed in *Ochlendra travancorica* and *Phyllostachys bambusoides*, respectively, both from natural stand (Table 1). In plantation grown, the fibre length of 3 year old bamboo (*Gigantochloa scortechnii*) was 3.77 mm. In *Bambusa bambos* it varied from 2-2.5 mm with the age. There was no significant correlation between fibre length, fibre diameter and fibre thickness. The minimal increase in fibre length with the increase in age was observed in the plantation bamboo. Hence, one year old culms can be used as raw material for pulping. However, in order to get heigher annual production of culms in the subsequent

years it is recommended that 36 months cutting cycle is ideally suitable for pulping purposes [4].

In conclusion, it can be said that, no appreciable change could be monitored between plantation grown bamboo (*Bambusa bambos*) and natural stands. It is conceivable that external factors such as soil conditions and climatic changes during fibre development might influence the fibre length.

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Influence of age on fibre and chemical charcteristics of plantation bamboo (*Bambusa bambos* (L) voss.

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Abstrct: The influence of age on the fibre and chemical character of one to six years old *Bambusa bambos* (L) Voss, were studied and the results are discussed in this paper. A gradual increase in chemical composition, fibre length and percent content of +50, +65, +100 mesh fibres could be monitored with increasing age. The results indicate that probably these bamboo species attain their maturity during the first year of growth. Comparing plantation bamboo with bamboo from tropical forests minimal variation was observed. Considering plantation management practices, it seems that 36 months old bamboo is better suited for pulping.

Key words: fibre; chemical charcters; *Bambusa bambos*; plantation bamboo;

摘要 文中研究和探讨了竹龄对1～6年簕竹人工林纤维和化学特性的影响。+50,+65 和 +100 目纤维的化学组份,纤维长度和百分比含量与林龄的增长而逐渐增加。结果表明这些竹种可能在第一年已达到成熟期。人工竹林与热带竹林相比变化很小。考虑到人工林的管理,36个月的老竹适合用于纸浆材。

关键词 纤维 化学特性 竹 人工竹林

INTRODUCTION

Bamboo is considered to be a unique raw material due to its quick growth, easy availability, straightness, smoothness etc. It is used for various purposes such as construction of rural houses, ladders, mats, baskets, pipes, handicrafts etc. But the highest demand is for the manufacture of paper. During the last few decades, it has become a major source of raw material for the Indian pulp and paper industry. The paper industry has an installed capacity of 2. 7 million tones covering 288 small, medium and large paper mills and produced about 1. 65 million tones of paper and paper board during the year 1988 (Tewari 1992).

The industry is presently facing problems of non-availabiltiy of suitable fibrous raw materials and inadequate quantity to meet its requirements. The supply of bamboo, so for the main raw material for the industry, has been dwinding in the recent years. Still bamboo account for 60 percent of the fibrous raw material requirement for the industry. In order to meet the present and future requirement of the productivity, but also to use the existing bamboo resources judiciously and efficiently, Considering this view, an experimental trial of *Bambusa bambos* (L) Voss was conducted at Kallipatty, near Sathyamangalam, Tamil Nadu, India.

During the extraction of bamboo from the forest, no definite cutting age is maintained. Rather, bamboos of different age groups is extracted indiscriminately. As a result pulping of a mixture of bamboos of different age groups may result in heterogenous cooking, producing inferior quality pulp, With a view to over coming these problem, this study is undertake to observe the influence of age of *Bambusa bambos* on fibre and chemical composition. This will help to determine and optimum cutting cycles for the

species under investigation. Previously a study on the influence of age of bamboo on pulping was conducted (Razzaque et al 1981, Bose et al 1988, Maheswari & Satpathy 1989, Kasim et al 1992, and Othman 1993). The present study is aimed at investigating the fibre and chemical characteristics of irrigated *Bambusa bambos* plantations.

MATERIALS AND METHODS

Preparation of the bamboo samples

The bamboo was reduced to sawdust by means of electrical saw. The saw dust was sieved initially with a 65 meshes and later with 200 meshes per sq. cm^2. The material retained during the second sieving was called "average wood" and was used for the analysis.

Proximate chemical analysis

The analysis was carried out as per TAPPI standard methods.

a) Cellulose— TAPPI T —203
b) Lignin —TAPPI T—222
c) Alcohol—benzene solubility — TAPPI T—202
d) 1% Na OH solubility — TAPPI T—212
e) Hot and Cold Water solubility —TAPPI T—207
f) Ash — TAPPI T—15

Fibre Analysis

For the determination of fibre length, pulp prepared under conditions given below was used.

1. Bath ratio: 1 : 3
2. Time to maximum temperature: 120 minutes
3. Cooking temperature: 127℃
4. Cooking time: 60 minutes
5. A Factor: 1300
6. Sulphidity: (18±)1%

RESULTS AND DISCUSSION

Fibre characters

The fibres are sclerenchy matous tissues and occur as caps over vascular bundles as isolated strands. A gradual minimum increase in fibre length could be monitored with increase in age. The fibre length obtained ranges from 20 mm to 2.5 mm in 1 and 6 year old *Bambusa bambos*. The influence of fibre on the physical properties of pulp have been reported of many scientific studies. Tamolang 1967, Zamuco et al., 1969 and Jamaluddin and Latif (1993). There are three principal factors affecting the pulp strength, fibre density, fibre length and fibre strength (Dinwoodie, 1965).

Fibre density is associated with cell wall thickness, (or) ratio of cell wall thickness to fibre diameter, (or) ratio of lumen diameter to fibre diameter and together with runkal ratio, they predetermine and dictate the tensile, bursting strength and folding endurance of the paper produced. Fibre length and fibre strength on the hand are essential for fibre bonding. As such for instance, tearing strength depend upon fibre length (Clark 1948. Wangaard 1962), fibre strength and cell wall thickness (Dinwoodie 1965).

Fibre length of forest bamboos is well documented (Razzaque et al 1981, Latif and Mustafa 1992, Jamluddin & Latif 1993) Fibre length is an important criterion in identifying the fitness of the wood in pulping as it has direct correction with the tearing strength of the paper (Bublitz 1980). *Bambusa bambos* under plantation attains its maturity during the first year of growth and fibre length slowly increases with age (Jamluddin & Latif 1993), which may very between species (Latif & Mustafa 1993). Fibres obtained from plantation bamboo forests are shorter in length (2 mm to 2.5 mm, Table—1) in comparison with those from counterparts in natural forests (*Bambusa polymorpha*, (4.19 mm). *Dendrocalamus giganteus* (3.39 mm), *D. hamiltonii* (3.36 mm), and *Oclandra travancorica* (4.03 mm) (Tewari, 1992).

Table —1 Fibre Length in *Bambusa Bambos*

Fibre Classification	years					
	1	2	3	4	5	6
Bamboo Density (g./cc)	0.588	0.593	0.598	0.610	0.617	0.622
Average fibre length (mm)	2.0	2.0	2.3	2.3	2.5	2.5
Chips	200.41	202.10	208.10	215.00	220.10	224.76

Analogous to fibre length, the percent content of +50, +100, and −100 mesh fibres showed gradual minimum increase in unbleached and bleached pulp (Table. 2 and 3). The life cycle of the bamboo culm will account for some of the variatious. It is conceivable that, external factors, such as soil conditions and climatic changes during fibre development might influence the fibre length (Othman, 1992).

Table —2 Unbleached Pulp Fibre Classification

Fibre Classification	years					
	1	2	3	4	5	6
+50 mesh fibre (%)	0.588	0.593	0.598	0.610	0.617	0.622
+65 mesh fibre (%)	2.0	2.0	2.3	2.3	2.5	2.5
+100 mesh fibre (%)	200.41	202.10	208.10	215.00	220.10	224.76
−100 mesh fibre (%)	18.88	18.96	19.00	19.09	19.09	19.10

Table—3 Bleached Pulp Fibre Classifiction

Fibre Classification	years					
	1	2	3	4	5	6
+50 mesh fibre (%)	76.10	78.20	79.12	80.27	80.40	80.70
+65 mesh fibre (%)	9.39	9.42	9.63	9.70	9.89	9.90
+100 mesh fibre (%)	5.10	5.24	5.40	5.42	5.50	5.51
−100 mesh fibre (%)	4.39	4.53	4.62	5.00	5.10	5.10

Chemical analysis

Proximate chemical analysis revealed gradual increase in the distribution of chemical components with age (Table — 4) which was also observed in *Bambusa polymorpha*, *B. tuida*, *Dendrocalamus hamiltonii*, *D. longispathus*, *D. strictus*, *Melocanna baccifera* (Guha 1980, Maheswari and Satpathy 1988). The lower ash content is favourable for pulping since it causes less problem in the chemical recovery system of a pulp mill. However the alcohol benzene solubles were 2% to 5% higher than *Bambusa vulgaris* (Kasim et al 1993). The cold and hot water, besides 1% alkali solubles were almost similar with that of other bamboos (Guha 1980, Maheswari & Satpathy 1988).

Generally, bamboo species with higher holocellulose had lower cold and hot water solubles, but with lower lignin content. Bamboos possessing higher holocellulose and lower lignin content are better suited for pulp and paper (Chen et al 1985). In the present study, proportionate increase of lignin with age was observed. The high lignin content indicates the need of more chemical consumption during bleaching. Corresponding increase in holocellulose,

lignin and ash contents with age were reported by Maheswari & Satpathy (1988), Jamaluddin et al (1992).

Table 4 Proximate Chemical Analysis

Age in years	Ash (%)	Cold water soluble(%)	Hot water soluble(%)	Alcohol benzene soluble(%)	1% NaOH (%)	Penstosans (%)	Ligin (%)	Cellulose (%)	Moisture (%)
1	1.20	4.00	4.47	7.50	20.50	19.10	28.00	60.01	40.0
2	1.50	4.00	4.60	7.50	21.90	19.32	28.50	61.20	40.0
3	1.70	4.20	4.90	7.90	22.50	19.53	29.00	62.50	45.0
4	1.90	4.20	5.10	8.00	23.00	19.62	30.50	63.30	50.0
5	2.10	4.30	5.80	8.00	23.00	20.33	31.50	64.50	50.0
6	2.30	4.50	5.95	8.00	23.50	20.20	32.00	65.60	50.0

* The first year to sixth year old culms were harvested for studying their proximate chemical composition. The material were processed as described under materials methods. The results are the average of the three independent experiments. Gradual minimal increasing trends of all the proximate chemical components was noticed.

CONCLUSION

The following conclusions can be drawn from this study.

1. Gradual minimal increase in the fibre length and chemical composition of this irrigated bamboo plantations, with increase in age.

2. 1 to 6 year old bamboo culms can be used an a raw material for pulping.

3. However, to increase the production of culms in the subsequent years, 36 months culm harvesting can be suggested. (For better plantation management culms of first two years (24 months) should not be harvested).

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东非市场导向的竹业发展研讨会在乌干达召开

由国际竹藤组织和商品共同基金共同举办，乌干达林业研究所承办的这次研讨会于2003年7月15～19日在乌干达首都坎帕拉召开。来自东非四国，乌干达，肯尼亚，埃塞俄比亚和赞比亚，以及国际竹藤组织，商品共同基金，联合国粮农组织和联合国环境基金的代表出席了研讨会。乌干达环境部副部长，驻华大使及中国驻乌使馆官员出席了开幕式。

在总结了国际竹藤组织在东非四国开展"竹子生产消费系统研究"的基础上，共同起草了"以市场为导向的东非竹业发展"项目建议书。国际竹藤组织副总干事陈绪和教授作了"促进东非以市场为导向的竹业发展"专题报告，傅金和博士介绍了"全球适地适竹"项目的成果。

会后考察了乌干达国家森林公园，实地察看了高山竹种 *Arundinaria alpina* 在天然混交林中的生长情况。

（傅金和）

Bamboo Plantations to Augment Pulp Production

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Abstract: Bamboo holds an important position among non - wood forest products mainly because of its value as a raw material for the paper industry. And yet, over exploitation associated with growing human population, destruction tropical forests and new demands on the resource for Industrial uses, especially by the pulp and paper industry, has resulted in wide - scale decimation of bamboo stocks, now we are left with the current situation of acute scarcity. The report on the National Commission on Agriculture brought out some figures about the current demand and output of the projected bamboo requirements for 1980 (4.250 million tonne) and 2000 (8.750 million tonne) and recommended the measures required to bridge the increasing gap between demand and supply (Shanmughavel, 1995). It was recognized that the availability of bamboo can only be sustained by raising elaborate bamboo plantation, and also to use the existing bamboo resources judiciously and efficiently.

Key words: bamboo; plantation; pulp production;

摘要 由于作为纸浆工业的原材料，因此竹子在非木质林产品中占有重要的位置。然而，过量采伐和人口增长，热带林的破坏以及工业原料的新需求，尤其是纸浆工业，导致竹子资源大量减少，目前面临锐减的形势。国家农业委员会发表的数字表明，1980 和 2000 年的需求与产出为425.0 万 t 和875.0万 t，需求与供给之间出现增长的差距。可以看出，只有通过人工林增长的方法和有效地利用现有的资源才能达到可持续性。

关键词 竹子 人工林 纸浆生产

Present state of pulp and paper industries

Pulp, paper and fibre industries in India are dependent on raw materials like bamboos, softwoods and hardwoods. Agricultural residues like bagasse, paddy straw, mesta, kernef and grasses account for 30 percent of the raw material, consumption of pulp, paper and board industries. The per capita consumption of paper in India is only 2 kg y^{-1} as against 200 kg y^{-1} in some advanced countries. The annual requirements of paper products by the year 2005 has been estimated to be 8.730 million $t \cdot y^{-1}$ as against the present installed capacity of 2.754 million ty^{-1}. (Table - 1). According to statistics collected by the Development council for pulp and paper, the installed capacity in India as of 1.1.2002 was 0.3 million of newsprint pulp, 0.196 was t, of rayon grade pulp and 0.040 million t. of paper grade pulp. There are 315 mills for the manufacture of paper and paper boards with a total installed capacity of 67,62,379 million $t \cdot y^{-1}$ (Table - 2).

Table 1 Raw material requirement for paper & paper board

year	capacity (million t)	production dependent on forest (million t)		capacity utilization	air dry of raw material (million t)
		80%		70%	
1981	1.816	1.453		1.017	2.848
1986	2.200	1.760		1.232	3.450
1991	2.810	2.240		1.568	4.390
1996	8.500	2.800		1.960	5.488
2000	4.250	3.400		2.380	6.664
2005	8.750	4.600		3.140	9.810

The Development council for pulp and paper in the Ministry of Industry appointed a raw material committee for pulp and paper. The shortage projected by this committee for the year 2005 were 0.300 million t of bamboo and 3.55 million t of wood. In addition, the committee projected the short fall in the raw material for newsprint production to be 0.161 million t of bamboo and 0.925 million t of wood.

Table 2 Paper, pulp, board mills and their installed capacity

particulars	category mt Y r^{-1}	No. of mills	installed capacity
Newsprint	0	5	300 000.00
Rayon grade pulp	0	4	196 250.00
Paper grade pulp	I	1	40 000.00
Pulp & paper mills with capacities above 20 000 mt.	I	30	1 457 300.00
With capacities from 10 000 to 20 000 mt	II	24	3 791 000.00
With capacities from 5 000 to 10 000 mt.	III	87	728 640.00
With capacities from 2 000 to 5 000 mt	IV	107	361 720.00
With capacities less than 2 000 mt.	V	57	87 469.00
Total		316	6 762 379.00

Research work on selecting bamboo species for paper – making

During the past five years, research work on pulp and paper making with different bamboo species has been going on. Based on the data derived from these, experiments, it was concluded that many species of bamboo such as *Bambusa bambos*, *B. vulgaris*, *B tulda*, *Dendrocalamus strictus*, *D. hamiltonii* are good for paper – making. Produce from these species meets more than 70 percent of the total requirements of raw material for the pulp and paper industry in India. Paper made from these were better than those produced from other species of bamboo in strength, and physical properties. (Othman, A. R. 1993, Shanmughavel, 1995, Shanmughavel and Francis, 1996)

Establishement of a bamboo plantation by paper industry.

The Development Council for Pulp and Paper in the Ministry, worked out scales of investment needed for pulpwood planting, their economics, suggestions for the management etc. The Ministry of Industry, recommended that, the paper industries should be produced 50% of their bamboo needs by the year 2005. This could be achieved by the afforestation of portion of the 82.8 million ha. Of wastelands available in the India. (or) by raising bamboo plantations in the vicinity of industries. The estimated area need of be afforested in 10 years either by the mills themselves (or) by the joint sector to make up the projected wood short fall found to be 0.71 million ha. This was based on an anticipated yield of 50 $t \cdot ha^{-1}$ with a 10 year period of rotation. The deficit of 0.5t. of bamboo could be made up by cultural operations in natural bamboo forests. This effort was suggested to be supplemented by encouraging the taking up of pulp wood in agro forestry on marginal farmlands and extension forestry schemes. The Ministry also recommended strategies for the flow of credit, changes in existing land laws and provision of incentives to encourage investments by mills on such long gestation crops (Tewari, 1991).

An advantage of raising plantation is that a steady supply of fibre raw material will be available in the vicinity of the paper mill. The cost of transportation, will therefore be lower. In India, bamboo plantations were raised near the following paper mills with great success.

1. Sri Seshasayee Paper Mills, Tamil Nadu
2. South India Viscose Limited, Tamil Nadu
3. Andra Pradesh Paper Mills, Andrapradesh

Economics of bamboo planting

Depending on the nature of use, bamboos are classified into (i) Commercial bamboo, and (ii) Industrial bamboo. The commercial bamboo used for all domestic purposes whereas industrial bamboo used exclusively for pulp and paper industries. Industrial bamboos are sold by the State Forest Departments and Forest Corporations directly to the paper mills.

Table 3 Comparative biomass accumulation

Bamboo Species	Age (Year)	Biomass (t/hm^2)	Reference
1. *Bambusa vulgaris*	3	7	Chinte, 1965
2. *Gigantochloa aspera*	4	10	
3. *G. scortechnii* (natural stand)	3	71.9	Othman, 1993
4. *G. scortechnii*	3	36.3	
5. *Bambusa bambos*	3	47.4	Shanmughavel, 1995

Comparison of pulp yield (%) of Plantation bamboo with hardwood species.

Various workers studied the economics of bamboo plantations. According to Chaturvedi (1986) the benefit cost (B/C) ratio 1:7 at 14.5 per cent rate of discount. Tewari (1981) has tested the economic bamboo plantation and found that the ratio was 1.85 at 14 per cent discount rate. Shanmughavel and Francis (1993) reported, the benefit - cost ratio as 1.51 at 12 per cent and 1.52 at 14 per cent discount rate. It is now widely recognized that cultivation of bamboo can provide a cost effective return in a short term (3 years).

Table 4 Comparison of pulp yield (%) of plantation bamboo with hardwood species

Name of species	Pulp yield (%)
1. *Plantation bamboo*	45.0
2. *Eucalyptus*	38.5
3. *Acacia decurrens*	39.3
4. *Acacia arabica*	37.0
5. *Erythronia suberosa*	39.3

Conclusions

To conclude, in the bamboo plantations the species of bamboo selected must be suitable for paper making, should be fast growing and should give a good yield. Research work on raw material storage and processing must be carried out. Research projects must be well designed and funds should be assured. Wide publicity must be given about the social, significance, economic utility and benefits of raising plantations. The government must also provide low interest loans to the paper industry for raising man - made bamboo forests. If full use is made of the bamboo resources and progressive techniques are employed, the paper industry will have a bright future.

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NEWS AND NOTES

an Expert Group Meeting on measures to increase the production and utilization of non-conventional food resources as sources of food in Africa. The meeting took place in Addis Ababa at the ECA Headquarters from 2 to 4 December 1996.

The main objective of the Meeting was to discuss the establishment of a Regional Research and Information Network for Non-Conventional Food Resources in Africa (NCFR), as a follow-up to a Workshop on the promotion of NCFR organized by ECA in collaboration with FAO in November 1992. The Workshop, which took place in Douala, Cameroon, was attended by 15 national and international experts from selected French-speaking African countries. The Network, whose creation was one of the major recommendations of the Workshop, would contribute to the consolidation of inter-country cooperation, with a view to promoting NCFR in order to improve the ecological balance and household food security.

The Meeting also examined the potential for, and limits to improving food security, especially for nutritionally vulnerable populations in African countries. It enabled participants to share experience, knowledge, information and ideas on production, use, management and promotion of NCFR, placing special emphasis on animal and plant resources from the wild flora and fauna, and including foods gathered from trees and shrubs.

In addition, the Meeting discussed the following themes: product identification for development based on nutritional, economic and ecological factors, market potential, indigenous knowledge and ethnobotany, plant domestication and small game farming.

Participants were invited in their individual capacity. The group comprised nutritionists, rural sociologists, agronomists, agroforesters, ethnobotanists, agricultural economists, etc., serving as NCFR development policy-makers or NCFR research and development officials in national, subregional, regional and international institutions and organizations of the private or public sector.

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BAMBOO AND RATTAN DATABASE IN SELECTED ASIAN COUNTRIES

The Department of Agricultural Economics, College of Economics and Management (CEM) of the University of the Philippines at Los Baños (UPLB), with funding from the International Network for Bamboo and Rattan (INBAR)/International Research Centre (IDRC) is currently conducting a research study entitled "Bamboo and rattan database in selected Asian countries". This study aims to consolidate statistical data on bamboo and rattan in China, India, Indonesia, Nepal and the Philippines which will become part of INBAR's Information System (INBARIS) and which will be made available to prospective users through the Internet.

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Comparison of bamboo fibre length in plantations and natural stands

Bamboo is a potential raw material for pulp and paper making due to its long fibres.

In India, natural bamboo resources are dwindling, due to overexploitation, shifting cultivation and extensive forest fires. The Raw Material Committee for Pulp and Paper, appointed by the Ministry of Industry, reported on the current and projected requirements for bamboo fibres, and recommended measures to bridge the increasing gap between demand and supply of raw material. The establishment of bamboo plantations was one of the recommendations. The Institute of Forest Genetics and Tree Breeding of the University of Bharathiar in Coimbatore is involved in research on bamboo fibre length (which influences the physical properties of the pulp), including the comparison between bamboo from natural stands and plantation-grown bamboo.

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PEOPLE AND PLANTS INITIATIVE IN THE PACIFIC

"People and Plants" is a joint Unesco, WWF and the Royal Botanic Gardens, Kew, (UK) global initiative on the sustainable use of plant resources (See also *Non-Wood News* 3 for more details on the programme.)

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EFFECT OF FERTILIZATION ON *BAMBUSA BAMBOS* PLANTATION

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Abstract

Fertilization experiments were conducted in five year old plantations of *Bambusa bambos* at Kallipatty, in RBD, with four treatments. The treatments comprised the following fertilization rates with 15-15-15 NPK fertilizer; 0, 100, 200 and 300 kg/ ha.$^{-1}$ The results showed that 200 kg /ha.$^{-1}$ of fertilizer was sufficient for increasing the production of *Bambusa bambos*.

Introduction

The bamboo is a fast growing plantation crop and is expected to consume a large quantity of nutrients to sustain production. A limited harvest of the culms is received in bamboo groves, where no fertilizing is carried. However fertilization is necessary to increase the production and periodical harvests. Several workers have reported, that the supply of nutrients considerably increased growth and biomass production in this crop (Huang,1987; Qiu and Maoyi, 1987; Raina *et al.*, 1988 and Totey *et al*, 1988). Still, the bamboo plantations are seldom given fertilization in commercial plantations. The present study was carried out to determine the optimum level of fertilization and correlate it with increasing its production.

Materials and Methods

Experiments were carried out on *Bambusa bambos* plantation at Kallipatty, Tamil Nadu. It has red soils of pH 7.4 to 7.8., elective conductivity 0.1, containing an average of 176 kg/ha. N, 33 kg/ha. P and 225 kg/ha. K, and average rainfall 310 cm/year, with relative humidity at 80% and of the mean temperature was 32° C.

Seedlings of *Bambusa bambos* were planted in 1987 with 6x6 m spacing in a 3 ha. area which accommodated 250 seedlings/ha. The trial was carried on five year old plants beginning 1992. For recording observations a total of 240 clumps were selected in the plantation of uniform height and growth. These were divided into four blocks with 60 clumps each. The randomized block design with four treatments, was used in these experiments. A basal fertilizer treatment at 15-15-15 NPK was uniformly given at 100, 200 and 300 kg/ ha.$^{-1}$ was taken with an unfertilized control. The number and diameter at breast height (dbh) of new culms produced were measured, one year after application of fertilizer (6th year).

Results and Discussion

The combined application of 15-15-15 NPK fertilizer showed a significant effect in the growth characteristics of *Bambusa bambos* (Table-1). A significant effect of the fertilizer on the size and number of new culms annually formed was obtained in the fertilizer dose of 200 kg/ha. and not in the case of 100, 300 kg/ ha. In comparison, the treatments 100, 200 and 300 kg/ha. differed grately from the unfertilized control. Similar type of results with other nutrient combinations were observed by several workers (Thomas, 1980; Raina *et al.*, 1988; Totey *et al.*, 1988, Wisu

TABLE-1: Comparison of Growth Characteristics of *Bambusa bambos* threated by at fertilizer different rates at fifth year

S. No.	Fertilizer rates (Kg/ha.) of NPK 15-15-15	Average diameter at DBH (cm)	Average height (m)	Average basal area (cm)	Number of culms	Number of nodes/ culm	Average length of rhizome (cm)
1.	Control	7.0±0.23	27.0±0.37	8.5±0.11	10±0.52	98	3.98
2.	100	7.5±0.25	27.5±0.20	9.0±0.30	13±0.41	101	4.97
3.	200	8.3±0.28	28.5±0.49	10.1±0.35	17±0.69	106	5.93
4.	300	8.0±0.26	28.0±0.56	10.0±0.33	15±0.49	103	5.00

and Thaiusta 1988. An improvement in the height and diameter of the culms in the fertilized plots was also noticed by Patil and Patil (1988) in *Dendrocalamus strictus*. Ferrer (1949) recorded a higher number of new shoots of bamboo in fertilized clumps than in the control. Ueda (1960) observed that the number of culms produced by *Leleba multiplex* increased several times as compared to the culms produced in the non-fertilized plots. Suzuki and Narita (1975) reported that the number of sprouts from the fertilized plots was 1.7 to 1.9 times more than that of the control.

The present investigation also revealed that the rhizome length was increased considerably in the fertilized block than unfertilized block (Table-1). Due to higher growth of rhizome in fertilized plot, the higher number of culms were observed. At a given site the production of new culms was mostly depended on the culms of the previous year, the degree of congestion and the clump age. In addition to this, application of fertilizers with different combinations also enhances the recruitment of culms. The fertilization also results in the production of higher number of culms i.e., 17 at the rate of 200 kg/ha^{-1}. The culms produced were distinctly taller and bigger in diameter*.

Conclusion

The combined use of 15-15-15 fertilizer had a pronounced effect on the growth of *Bambusa bambos*. Fertilizer application at 200 kg/ha.$^{-1}$ is recommended to increase the yield of *Bambusa bambos*.

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STUDIES ON STORAGE OF GIANT GRASS (*BAMBUSA BAMBOS*) SEEDS

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Abstract : The effect of seed moisture content and storage temperature on the viability of *Bambusa bambos* seeds was studied. The study showed that seed viability can be extended by reducing the initial moisture content before storing. Seeds stored at low temperature (2 to 4°C and -5°C) maintained a high percentage of viability for up to 24 months.

INTRODUCTION

Bambusa bambos (L.) Voss, is one of the most important species found almost all over India, and is a very densely tufted bamboo with curving branches. Culms are usually bright green and shining usually 15 to 30 m high and 15 to 18 cm diameter, nodes slightly swollen. It is generally used for constructional purposes, handicrafts and in pulp and paper industries (Shanmughavel and Francis, 1995).

Bamboos differ significantly from other vegetation because of the mechanism of flowering. *Bambusa bambos* is a gregarious flowering which takes place during November or February depending on the location. Usually the seeds are collected during January and April. The quality of seeds is mainly dependent on their maturity and collection conditions at the time.

The bamboo seeds longevity varies from species to species but they are generally viable up to 1 to 2 months under ambient conditions.

Seed germination is strongly correlated with moisture content (Anantachote, 1987). The size and shape of seeds also varies within species. Longevity of different bamboo seeds under different storage conditions were studied (White, 1974; Gupta and Sood, 1978, and Thapliyal *et al.*, 1991). Seed germination ranged from 7 to 80% (Francis *et al.*, 1998). The present investigation was aimed at to study the effect of different seed moisture content and storage temperature on the viability of *Bambusa bambos* seeds.

MATERIALS AND METHODS

Seeds of *Bambusa bambos* were collected from District Forest Office, Sathyamangalam, in February1996. These seeds were divided into five groups and the moisture content was reduced to 10.2, 7.8, 7.5, 7.3 and 5.9% respectively. (The moisture content of a sample is the loss in original weight when it is dried. It is expressed as a percentage of the weight of the original sample). The moisture content was calculated on a wet weight basis. The five groups of seeds were packed in sealed polyethylene bags and were used in experiments each group consisting of 100 seeds.

Experiment was set up to investigate the effect of room and low temperature on seed viability. The five groups of seeds were stored for 24 months under three different conditions: at room temperature (25 to 30°C), cold room (2 to 4°C) and deep freezer (-5°C).

For each treatment four replications of 100 randomly selected seeds were tested for germination after 0, 3, 6, 9, 15, 21 and 24 months of storage. All seed samples were separately sown into the surface of the sand contained in plastic boxes in controlled environment germinator with 90% relative humidity, at 20-30°C. Results were expressed in terms of percentage of germination.

Table-1: Average germination percentage of *Bambusa bambos* seeds of five different initial moisture contents (ML) stored under three different conditions for 24 months

Storage temperature	Initial moisture content	Initial moisture %	Months					
			3	6	9	15	21	24
25 to 30°C	10.2	89.0	89.0	60.2	32.7	1.5	0	0
	7.7	92.2	84.7	85.2	74.5	17.0	0	0
	7.5	92.7	92.5	90.2	78.0	30.5	0	0
	7.3	88.5	87.0	88.5	82.5	26.2	0	0
	5.9	95.5	90.0	86.5	82.7	71.5	1.2	0
2 to 4°C	10.2	89.0	88.2	82.7	86.0	89.2	90.7	89.7
	7.7	92.2	87.5	91.2	90.0	92.7	92.2	89.2
	7.5	92.7	91.2	92.0	89.2	92.5	96.0	89.7
	7.3	88.5	91.0	91.5	86.5	94.7	94.7	92.5
	5.9	95.5	90.7	92.5	88.2	91.2	93.7	91.0
-5°C	10.2	89.0	93.2	88.7	89.0	90.2	90.0	89.7
	7.7	92.2	89.7	87.5	87.7	94.7	89.5	90.0
	7.5	92.7	86.2	90.2	92.0	93.7	92.7	89.5
	7.3	88.5	90.7	91.2	95.2	93.5	87.7	89.7
	5.9	95.5	89.2	94.0	83.7	89.7	92.2	91.2

Percentage germination of seeds stored at 2 to 4°C and -5°C were average of two sets of seed samples.

RESULTS

The initial germination of the five groups was 89.0, 92.3, 92.8, 88.5 and 95.5% respectively (Table-1). The germination of seeds with the highest moisture content and stored at room temperature was found to be lowest after six months. Seeds stored in the cold room and deep freezer remained viable at all moisture content levels until 24 months.

The results of the analysis of variance of the seed viability data are presented in Table-2. This show that with the increase in storage time the influence of temperature and moisture content were marked.

The analysis of variance showed that the different treatment factors were not significant at three months (Table-3). The initial moisture content and storage time influenced seed viability when stored for 24 months. Similar results were observed by Thapliyal *et al.* (1991) in the seeds of *Bambusa tulda*.

CONCLUSION

Seeds of *Bambusa bambos* can be stored for about 24 months and the viability can be extended by reducing the initial moisture content before storing which helps in maintaining viability up to

Table-2: Analysis of variance of *Bambusa bambos* seeds stored for three, six and nine months under 15 treatment combinations

Source of variation	3 months		6 months		9 months	
	DF	F	DF	F	DF	F
Treatment	29	1.082	44	3.514	59	10.625
A	4	2.441	4	9.444	4	24.22
B	2	0.134	2	5.53	2	41.655
C	1	2.717	2	5.696	3	27.002
AB	8	0.42	8	2.115	8	10.975
AC	4	2.912	8	4.179	12	5.502
ABC	8	0.42	16	1.708	24	4.825
Error	90		135		180	
Total	119		179		239	

A - moisture content; B - storage temperature; C - storage time.

Table-3: Analysis of variance of *Bambusa bambos* seeds stored for 3 and 24 months in the cold room and deep freezer

Source of variation	3 months		24 months	
	DF	F	DF	F
Treatment	19	0.977	69	1.314
A	4	1.189	4	3.287
B	1	0.002	1	0.03
C	1	1.097	6	2.707
AB	4	0.43	4	0.943
AC	4	2.311	24	1.391
BC	1	0.002	6	0.899
ABC	4	0.432	24	0.778
Error	60		210	
Total	79		279	

A - moisture content; B - storage temperature; C - storage time.

nine months. Seed samples stored at room temperature lost their viability within 21 months. In comparison seeds stored for 24 months under low temperature such as in the cold room (2 to 4 °C) and deep freezer (-5°C) can maintain high percentage of viability (89.2 to 92.5%) and were able to germinate within three to four days.

ACKNOWLEDGEMENT

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II

Studies on the Vegetative Propogation of Bamboo (*Bambusa bambos* (L.) Voss)

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Introduction: The propagation of bamboos by seed is restricted, since bamboos flower and seed only two(or) three times in a century. Due to long interseeding intervals, the propagation is done vegetatively. Various methods of vegetative propagation like offset planting, layering, rooting of culm and branch cuttings are used for propagation of bamboos. The success and limitations of such propagation methods have been reported. [1,2]. The present study was conducted with the objective of developing suitable methods for propagation of bamboos using branch cutting methods.

Material and Methods

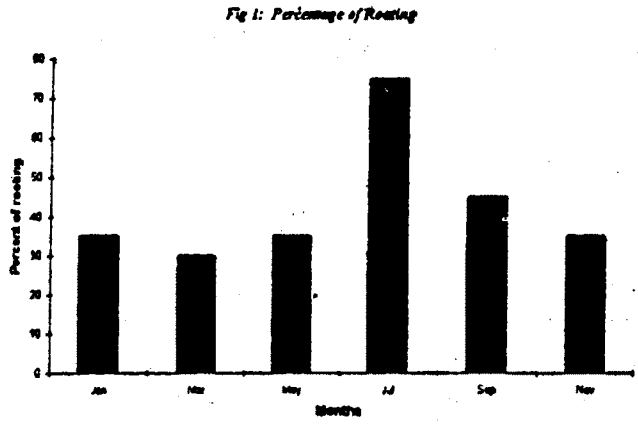
Site Description : The study area of plantation *Bambusa bambos* is located at Kallipatty, between 10° 28' and 12°E of latitude and 76° 59' and 77° 47°N longitude. It altitude is about 540 m above MSL. Soil in the area was laterite, red to brown in colour. Soil pH was 7.5. The total soil concentrations in N, P, K, Ca and Mg were 3800, 360, 3000, 1600 and 1800 kg ha^{-1} respectively. The mean temperature and rainfall is 31°C and 600 mm respectively.

Branch Cuttings : Branch cuttings from the bottom, middle and top portions of the healthy culms were taken from the clump of *Bambusa bambos* with a sharp knife [3]. The branches were cut at its basal portion, the leaves and side branches were removed and cuttings with two internodes were prepared. Cuttings were taken at an interval of 3 weeks starting from the month of July. The cuttings were immediately transferred to the nursery.

A natural rooting medium (mixture) was prepared by mixing rice husk, dried powdered cow dung, charcoal and sandy soil in equal proportions. The mixture was filled in black polythene bags of 45 cm height. The cuttings were inserted into the polybags vertically. The planted cuttings were placed in a thatch to protect from direct light. They were regularly watered in the morning and evening.

Results and Discussion

Branch Cuttings: The cuttings sprouted within 40 days after planting, and root development was also observed within this period. Rooting efficiency was better in the samples taken from the



bottom region. The rooted cuttings were transferred to the soils in rainy season. The performance of the cuttings planted during different months are presented in Fig. 1. It reveals that nearly 75 per cent survival and growth took place during the month of July followed by September.

Conclusion : The study established that use of branch cuttings was most suitable and effective for raising bamboo, on commercial scale.

Acknowledgement : The first auther is grateful to the Council of Scientific and Industrial Research (CSIR), New Delhi for providing financial assistance in the form of Senior Research Fellowship.

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HARVESTING TRIALS IN PLANTATION BAMBOO (*BAMBUSA BAMBOS* (L.) VOSS.) STANDS

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Abstract

Harvesting trials were conducted in the plantation *Bambusa bambos* stand at Kallipatty, Tamil Nadu using the completely randomized design with eight treatments which varied in the intensity of harvesting in each clump. The production of bamboos was measured. The result indicated that clear cutting killed the bamboo plants, but selection cutting of those culms older than three years increased their production.

Introduction

Bamboos are tree grasses which are important in economy of certain parts of tropical America and South-East Asia, as they provide food and construction material. Bamboo is perhaps the only natural resource which is put into use for innumerable purposes, viz., food, fodder, shelter, medicines, musical instruments, handicrafts, furnitures, pulp and paper, agricultural implements and for various other articles of day to day uses. Some of the recent uses of bamboo are bamboo parquet, laminated bamboos, strips for aircrafts, bamboo reinforced concrete for low cost housing and artificially shaped bamboo for various decoration items.

It is estimated that the bamboo bearing area in India is about 10 million ha. and annual potential yield is around 4.5 million tonnes (Tewari 1992). Bamboo plantations are being raised extensively to fulfil the raw material requirements of paper and rayon grade pulp (Shanmughavel 1995). The harvesting of bamboo is not supervised by any authority, nor any tending is ever practised. The tremendous amount of both bamboo culms and shoots taken out from the natural and plantation stands, without any silvicultural practice, has resulted in depletion of the bamboo resource.

With these considerations in mind harvesting trials were conducted in a plantation stand of *Bambusa bambos* (L.) Voss. at Kallipatty, Periyar District, Tamil Nadu, to determine the most effective means of increasing production.

Material and Methods

Site Description: The study area of *Bambusa bambos* plantation located at Kallipatty falls in between 11°28' and 12° E latitude and 76° 59' and 77° 47' N longitude. Its altitude is 540 m above MSL. The soil is laterite, red to brown in colour and sandy loam in texture. The mean temperature and rainfall of the area is 31°C and 600 mm respectively.

Harvesting Trial: The experiments were carried out in a plantation bamboo stand of *Bambusa bambos*. A completely randomized design with five replications was used in the trial. The treatments included the following levels of cutting in each clump.

T_1 = 50% cutting of culms older than two years.

T_2 = 100% cutting of culms older than two years.

T_3 = 50% cutting of culms older than three years.

T_4 = 100% cutting of culms older than three years.

T_5 = 50% cutting of culms older than four years.

T_6 = 100% cutting of culms older than four years.

T_7 = 100% cutting of all culms at any age (or) clear-cutting.

Con. = Control (or) no cutting.

Forty clumps were selected for uniformity and a treatment was randomly applied to each clump. The number and diameter at breast height of the new culms produced each year were measured.

Results and Discussion

From the eight treatments including the control, it was found that clear - cutting (T_7) completely destroyed the *Bambusa bambos* clumps. They could not give rise to any new shoot that could develop into a new culm after one year of clear-cutting of clumps. Small branches were found at the cut ends of the culms in each clump, and the plants remained grass-like condition. Similar results were reported in *Thyrostachys siamensis* (Suwannapinunt *et al.* 1978; 1982) and in *Gigantochloa hasskarliana* (Suwannapinunt 1988).

Among the first six treatments and the control (T_1, T_2, T_3, T_4, T_5, T_6 and Con.), the harvesting methods had pronounced effects on the production of new culms, their height and diameter (Table-1). When all culms older than three years and which are physiologically inactive (Ueda 1960; 1968) were harvested in T_4, the plants produced more culms i the following years. But when culms older than fou years were harvested (T_6), the annual recruitment o culms and its size were reduced. On the other hand when more young culms, which are physiologicall active (Ueda 1960; 1968) were harvested in T_3, th bamboo plants produced comparatively fewer culm in the following years. In the case of T_5, where som inactive old culms were taken off and some left ou the production decreased in the following years. I the control where no harvesting was carried out, th annual production of culms remained constant.

It is quite clear that harvesting of *Bambus bambos* should be done by cutting culms older tha three years, while leaving the younger ones, sinc these are physiologically more active, have vigorou rhizomes and can produce more culms (Ueda 196(1968).

Conclusion

By clear-cutting all culms in *Bambusa bambo* clumps, the plants could not form new culms an eventually died. On the other hand, by selectiv cutting of culms older than three years in each clump the plants produced more new culms, which are o the same size as those cut; hence production can b both increased and sustained.

Table-1: Total number of new culms produced in three years after treatment of *Bambusa bambos* clumps in plantation stand at Kallipatty

S.No.	Treatments	Number of Culms Produced	Average Height (m)	Average Diameter (cm)
1	T_1	18 ± 2	8.5 ± 1.0	3.5 ± 0.5
2	T_2	19 ± 3	9.0 ± 1.0	4.5 ± 1.0
3	T_3	26 ± 6	24.5 ± 2.5	7.5 ± 1.0
4	T_4	34 ± 8	27.5 ± 3.0	8.3 ± 1.5
5	T_5	20 ± 4	20.5 ± 1.5	5.5 ± 1.0
6	T_6	22 ± 4	21.0 ± 1.0	6.3 ± 0.5
7	T_7	Nil	Nil	Nil
	Control	18 ± 3	9.5 ± 1.0	4.0 ± 0.5

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(37)

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Short Communications

Performance of *Bambusa bambos* Plantations at Kummittapuram Sathyamangalam Forests, Tamil Nadu

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Introduction : Bamboo is a vernacular term for members of sub-family Bambusoideae of family Poaceae, the grasses. In view of the decreasing average under forest cover and simultaneous increase in demand for bamboos, foresters have no option but to think in terms of increasing bamboo production within the existing natural stands of bamboo forests which are estimated to occupy about 12 per cent of the total forest area in India [2]. Various workers already studied the growth characteristics of *Bambusa bambos* in the natural forests as well as plantations [1-6]. In order to increasing bamboo production, the bamboo seedlings were planted in the Kummittapuram forest area, Sathyamangalam Division, by the office of the Deputy Conservator of Forests, Bamboo Estates, Gobichettipalayam during 1990. This study was taken up to see the performance and survival of transplanted seedlings in the Kummittapuram area of Sathyamangalam Forest Division.

Study Site : The study area is located between 20°-30°N lat. and 90° E long. The climate of the area is monsoonic. This area has red soils. Soil pH is between 7-8. The maximum soil nitrogen, phosphorus and potassium were determined to be 160 kg/ha, 22 kg/ha, and 180 kg/ha respectively. The mean annual temperature is 30°C and the rainfall is about 1005 mm.

Trials and Observations : The seedlings in the nursery were up rooted carefully and planted in the pit size of 45×45 cm during August 1990, with a spacing of 6 m×6 m. The plantation details are given below :

Place	Area (ha)	No. of seedlings
Beat—I	22.1	6140
Beat—II	28.5	5000
Beat—III	9.6	2000
Beat—IV	12.0	3000
	Total	16140

The planting was completed before the monsoon got fully set in. To provide better initial growing environment to the seedling to upper halves of the pits were filled up with a mixture of 25 g Vijay Complex (N, P, K) 17:17:17 per plant, while the lower halves were filled up with original soil. Soil operations like gully plugging was done. Brushwood fence were made in each seedling to prevent damage from ro-

dents, grazing and browsing animals. The fire is the most detrimental to seedling regeneration. Therefore the plantation area needs protection from fire. Two fire watchers were appointed to oversee the plantation from fire.

Observations : The growth data, survival per cent and seedling height are given in Table 1. Perusal of data given in Table 1 reveals that in respect of survival percent Beat II showed maximum percent (95%) followed by Beat III (90%), Beat I (75%) and Beat IV (70%). It is the survival percent, which determines the suitability of the species to the site if the growth is in normal range. In respect of height growth Beat II (1.15m) followed by Beat IV (0.95m), Beat III (0.85m) and Beat I (0.70m) were found growing in this order. Here the *Bambusa bambos* seedlings giving 0.70—1.15m height growth have been considered as successful, reason being that this is the introductory trial and height growth can be given importance only when it differs extra ordinarily from this performance on a normal site. The result reveals that, the plantation raised so far have attained grand success by getting the survival per cent from 70-95.

Table 1. Average growth data.

Place Kummittapuram	Survival (%)	Average height (m)	Average diameter (cm)
Beat I	75	0.70	1.5
Beat II	95	1.15	2.5
Beat III	90	0.85	1.6
eat I V	70	0.95	1.8

Table 2. Average recruitment of culms.

Place Kummittapuram	Average produced	Number of culms/clump during the year 1992	1993
Beat I	—	2	4
Beat II	2	5	8
Beat III	1	3	5
Beat IV	—	2	3

In conclusion, to get maximum yield in due course, the plantation management should be continued for some more years.

Results and Discussion : It was observed that average culm emergence in Beat II (2 culms/clump) and Beat III (1 culm/clump) took place during 1991, i.e., one year after planting. Whereas in Beat I and IV no culm emergence took place during the first year. However, culm emergence took place in all the four Beats during second year. The average annual recruitment of culm gradually increased in the subsequent years and numbered at 4, 8, 5 and 3 per clump in Beat I, II, III and IV, respectively. The culm emerged in the first year were short in length and narrow in diameter at breast height (DBH). Culms produced in the subsequent years were taller and bigger in diameter than those produced in the past years and such trend continued. The results obtained in this study were in general agreement with earlier results [2, 4, 5].

Therefore, while with the present study, it is not possible to prescribe the first harvesting year for the species planted.

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Studies on Growth of Transplanted Seedlings of *Bambusa bambos* at Chickally, Sathyamangalam Forest Division, Tamil Nadu

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Abstract : The growth and survival per cent of transplanted *Bambusa bambos* seedlings at Chickally, Sathyamangalam Forest Division was studied during November 1993. The survival per cent ranges from 70 to 80 per cent in three beats. The height growth of seedlings showed 0.85 m to 1.05 m. The annual recruitment of new culms increased every year, and the maximum recruitment was observed during the monsoon season. It was also observed that the dry weight of bamboo also increased.

Key words : *Bambusa bambos, Growth, Annual recruitment, Biomass.*

Introduction : Bamboo are an important forest produce in Asia and the Pacific. The total forest area covered by bamboos in the country is about 9.6 million hectares [4]. This is about 12.8 per cent of the total forest area of the country. Though a major of the requirements are met from the natural forests, the increasing demand can be met only through plantation. Various workers already tried the standardisation of cultural practices [1, 2, 3, 5]. In view of the increasing bamboo production within the existing natural stands of bamboo forests, the *Bambusa bambos* seedlings were planted in the Chickally forest area, Sathyamangalam division by the office of the Deputy Conservator of Forests, Bamboo Estates, Gobichettipalayam during August 1992. The present paper reports the results of trials in which the transplanted seedlings were given protection from grazing, soil treatment and application of fertilizers.

Material and Methods

Study Site : The study area (Beat I–III) lies between the 18°30′ N lat. and 80°5′ E long. The climate of the area is monsoonic. This area has red soils. Soil pH is between 7 to 8. The maximum soil nitrogen, phosporus and potassium were determined to be 150 kg/ha, 30 kg/ha and 200 kg/ha respectively. The mean annual temperature is 23°C and the rainfall is about 1200 mm.

Preparation of Nursery : Nursery beds of 10×5 m were prepared in the field and filled with a mixture of soil and sand (3:1). The seedlings when about 7 cm in height were pricked out from the polythene bags. About 25–26 seedlings were planted in 1 m^2 off raised

nursery bed. (One week prior planting the nursery bed were drenched with 0.01% aldrex and 0.05% bavistin to prevent termite and fungal attack respectively). Watering was done 2–3 times a day and care was taken to avoid oversaturation. Nursery beds were provided with a thatch to protect the seedlings from direct sunlight.

Transplanting : The seedlings in the nurseries were uprooted carefully and transplanted to 45×45 cm pit in the fields during August 1992. The seedlings were planted with 6 m×6 m spacing in 49.3 ha open area.

Beat I	13.7 ha—3808 seedlings	
Beat II	11.0 „ —3058	„
Beat III	14.6 „ —4058	„

The planting was completed before the monsoon got fully set in. To provide better initial growing environment to the seedlings the upper halves of the pits was filled with a mixture of 25 gram Vijay Complex 17:17:17 per pit, while lower halves were filled up with the original soil. Soil treatment and Gully plugging was also done. Protection against damage by rodents, grazing and browsing animals was provided by making brushwood fence. Two fire watchers were made responsible for detection and reporting of fire to the fire reporting station of the concerned beat.

Observations : In each Beat, 5 ha has been selected randomly to assess the growth and survival per cent of the transplanted seedlings. The observation was continued for one full year. The annual recruitment of culms/clump during the subsequent years was noted. The estimation of biomass of different ages of bamboo was also done to study the performance of the bamboo plantation.

Results and Discussion :

Growth Data : Perusal of data given in Table 1 reveals that in respect of survival percent Beat II (80%) Beat III (75%) and Beat I (70%) are successful for the Chickally area. In respect of height growth Beat II (1.05 m), Beat III (0.90 m) and Beat I (0.85 m) were found growing in this order. It is the survival per cent which determines the suitability of the species to the site, if the growth is in normal range. This was the first time, the seedlings were planted in the forest area, after a prolonged interval. The plantation raised so far have attained grand success. In order to get maximum yield per ha the plantation management should be continued for some more years.

Table 1. Average growth data.

Place	Survival (%)	Height (m)
Beat I	70 ± 2	0.85
Beat II	80 ± 4	1.05
Beat III	75 ± 3	0.90

Annual Recruitment of Culms : The average annual recruitment of culms/clump increased during subsequent years. The maximum recruitment of culms was observed in Beat II (16) followed by Beat III (13) and Beat I (11)

(Table 2). The higher recruitment of culms took place during the rainy season. Similar results were observed by Shanmughavel and Francis [3] and Vinod Kumar [5]. The culms emerged in first year were short in length and narrow in diameter at breast height. Culms produced during subsequent years were taller and bigger in diameter than those produced in the past years and such trend continued.

Table 2 Annual recruitment of culms/clump.

Year	Beat I	Beat II	Beat III
1993	3 ± 1	6 ± 2	5 ± 2
1994	8 ± 3	10 ± 4	9 ± 2
1995	11 ± 2	16 ± 3	13 ± 4

The annual recruitment of culms/clump found to be maximum during the rainy season.

Biomass of Bambusa bambos : In order to study the productivity of the plantation 15 bamboos felled randomly in each Beat. After felling, bamboo was separated into culms, branches and leaves. The fresh weights were taken in the field. The representative samples were brought to the laboratory and dried at 103± 2°C in a hot air-oven. The productivity (biomass) of bamboo increased year after year and observed maximum during 1995. The biomass was found in the order of Beat II (1.800 kg/bamboo) followed by Beat III (1.450 kg/bamboo) and Beat I (1.200 kg/bamboo) (Table 3). Similar results were observed by Shanmughavel and Francis [3].

Table 3. Biomass of *Bambusa bambos* (kg/bamboo^{-1})

Year	Beat I	Beat II	Beat III
1993	0.400	0.800	0.500
1994	0.900	1.500	1.000
1995	1.200	1 800	1.450

There is no much difference between dry weight of various components of bamboo hence average value was taken into further consideration.

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BAMBOO CULTIVATION PROBLEMS AND PROSPECTS

by

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Summary

This paper, discuss the bamboo cultivation methods, its problems and prospects. The problems of bamboo cultivation relate to seed collection, vegetative propagation, soil moisture conservation, plant protection, weeds, grazing & fire and clump congestion. Suggestions were given to overcome the problems. The prospects of cultivation relate to economic analysis and employment generated. Cultivation of bamboo can provide a cost effective return within a short rotation (3 years).

Introduction

Bamboo is integral to the culture of South - East Asia. Ever country has its own indigenous bamboo species. Over 75 genera and 1250 species are reported to occur all over the globe. India perhaps has the world's richest resources of bamboo, claiming about 130 species occurring over an area of 9.57 million ha. This is about 12.8% of the total forest area of the country. However bamboo resources in their natural habitat is dwindling, due to over exploitation, shifting cultivation practices and forest fires. A sustainable availability can be ensured only by elaborate bamboo cultivation (Shanmughavel 1995). The present cultivation technique is based on the experience rather than on scientific basis. Species which have attained a crop status in agriculture have decades of directed endeavor behind them. Bamboo have not attained the same status due to lack of sustained investigations. A few problems of fundamental and applied nature and bamboo cultivation prospects are listed below.

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Cultivation techniques

Generally bamboo are cultivated by planting off-sets (or) rhizomes, as seeds are not readily available except in seed years, which again are few, although seedlings obtained from tissue culture techniques can also be used. Planting pits are prepared about two months ahead of the planting time and the pit as well as the dug - up soil allowed to weather. Seeds (or) seedling were planted in the field at a spacing of 6m x 6m which give 250 seedlings/hectare planted. For off-set planting, the collection of off-sets should be done very carefully. They should be properly dug up so that the buds are not damaged in anyway. These are then to be transported as quick as possible to the planting site, ensuring protection against exposure and kept puddle under shade before planting. The time of planting is a most decisive factor in the ultimate success of the plantation. Planting work must be undertaken immediately after the first showers of the monsoon. In plantations, profuse watering is required, but over watering is avoided. All casualties must be replaced in due course. The plantation will be ready for exploitation within three to five years.

Production of culms

All the germinated seedlings produces rhizomes, which on turn develop into new rhizomes that produce lateral culms, which are the chief causative for the total biomass yield. The number of culms developed from the rhizomes totally constituted to a clump. During the first year, 3 to 4 culms were produced. The average annual production of culm generally increased year after year. The culms produced during first year is shorter in length and smaller in diameter, but culms from subsequent years will be longer in length and bigger in diameter.

(I) Problem of cultivation

There are many irremediable management problems, if large scale plantation is planned. These problems related to seed collection, vegetative propagation, soil moisture conservation, plant protection, weeds, grazing and fire, and clump congestion.

Seed Collection:-

Seeds of bamboo resemble grains of paddy (or) wheat and very light. Seeds for direct and nursery sowings should be obtained direct from the source. Possibilities of raising bamboo plantations from seeds is unreliable due to the long and unpredictable flowering habit of the bamboos (from 25 to 60 years) (Uchimura 1980). Besides, the seeds have no dormancy period and are viable only in a short period (Anonymous 1948). It is suggested that, a practicle and cheap method of prolonging the viability of seeds has to be developed. Some basic studies on seed biology should be undertaken.

Vegetative Propagation:-

Various methods of vegetative propagation like off-set planting, layering, rooting of culm and branch cuttings are used for propagation of bamboos. The success and limitations of such propagation methods have been reviewed by Banik (1980) and Haan (1980). All the four methods mentioned above have their advantage and disadvantage. The use off-set planting and branch cuttings has proved to be quite successful. But for large scale plantations, however the off-set planting is not the best choice as they are bulky and difficult to transport. Seedlings obtained from tissue culture techniques can also be used for raising bamboo plantations. It is clearly understood that, those who cultivate bamboo would face the difficulty in getting the seedlings.

Hence, the seedlings should be provided free by the forestry department, including technical know how. There should be a motivation for each (or) a group of villages trained in bamboo culture. The farmer should be paid a nominal amount per year 3 to 4 years towards maintenance and protection of bamboo cultivation.

Soil Moisture Conservation:-

Soil moisture is a very critical factor. The annual production of culms mostly depended on the soil moisture. It is important to maintain humidity in the soil. Any measure which improves soil moisture is worthwhile. Ploughing between rows of clumps in one direction and not in a crisscross manner for fear of cutting roots on all sides which have a very desired effect. Mounding or heaping earth around the bamboo culms should be carried out each year before the rainy season (Shanmughavel and Francis 1995).

Plant Protection:-

The formation of bamboo plantations is not without accompanying risks. Young plants, most of which develop the rhizomes in the seedling stage, are subjected to predation by rats, porcupines, squirrels, pigs, deer, cattle and goats. But the major damage are cause by man, monkeys and elephants. Effective fencing is most essential in the early stages. In the nursery wire - netting should be used to protect the seedling beds from hares, which damage the young plants. Insect attack on the new growing culms, (or) on cut bamboos, is a normal factor in bamboo management. In the life of growing culm, the stage of greatest susceptibility to fungal attack is the komali stage.

The green komali turns brown and comes off easily when pulled, leaving the area of transformation soft and brown, smelling strongly of molasses. The pathogenic fungi kill a large percentage of komalis and this is commonly experienced in heavy soils of impeded drainage. The measure like drenching the clumps with blue copper in advance. This may have to be repeated as long as komalis continue to appear. Plant protection measures will go a long way in stepping up the yield.

Weeds:-

Weeds are the another important problems during the initial stages of plantation. For this, weeding was done as and when required. If there is weed competition, the bamboo regeneration suffers more (or) less heavily and shade also thins it out (Kumar 1992).

Grazing and fire:-

Grazing and fire are most detrimental to seedling regeneration. Therefore the plantation area needs protection from grazing and fire. When protection against grazing and fire is not provided the regeneration on form of seedlings are grazed/browsed and killed (Kumar 1992).

Clump Congestion:-

Congestion in bamboos is one of the most serious problems of management of clumps. Damage by human is probably one of the main causes of congestion in bamboos. Clump congestion may be due to (a) too much of soil compaction, (b) insufficient soil depth for rhizome and (c) development of too many rhizomes in a season. The first problem can be overcome by closing the area to grazing.

The second constraint can be overcome by mounding in order to influence the development of future rhizomes outwards (Shanmughavel and Francis 1995). Development of too many rhizomes, where soil moisture is abundent such as on river banks, will caurse congestion and this can be avoided by removing the excess at the komali stage.

Prospects of Bamboo Cultivation

Major uses of bamboo such as structural material for building purposes and raw material for the pulp, paper and panel product industries are based on the culm portion of bamboo. The other parts of bamboo plant such as leaves, seeds, rhizome and even the young bamboo shoots are equally useful to the mankind. A brief account on the prospects of bamboo cultivation have been discussed here.

Economic Analysis

Depending on the nature of use, bamboo are classified into i) Commercial bamboo, and ii) Industrial. The commercial bamboo are used for all domestic purposes where as industrial bamboo used exclusively for pulp and paper industries.

The price on commercial bamboo varies according to its length and girth. Hence is sold as per its length and girth basis. Different sizes normally sold in market are as given below.

Girth(cm)	Length (m)	Remarks
9 - 12	3 - 5	Each length class
12 - 15	5 - 7	has all girth classes
15-20	7 - 9	
& Over 20		

In Government depots bamboo are sold in lengths varying from 3.10 to 7.50 m and girth varying from 9 cm. to more than 20 cm. Bamboo purchased from the Goverment depots is converted into smaller sizes according to the local requirements.

Industrial bamboos are sold by the State Forest department and Forest Corporations direct to the paper mills. Thinner ends of the bamboos are converted into pieces of 1 m and 2 m lengths and supplied to the paper mills.

The economic of bamboo plantations were studied by various researchers. According to Chaturvedi (1986) the benefit cost (B/C) ratio of 1:7 at discount 14.5 percent. In another study Tewari (1981) has tested the economic parameters on casts and benefits data of one hectare bamboo plantation and found the benefit cost (B/C) ratio as 1.85 at discount of 14 percent. Shanmughavel and Francis (1993) reported that, benefit cost (B/C) ratio as 1.51 at discount of 12 percent and 1.52 at discount of 14 percent. It is now widely recognized that cultivation of bamboo can provide a cost effective return in a short term (after 3 years).

Employment Generation:-

Bamboo is a multipurpose species and its processing is labour intensive providing opportunities of employment and may be converted to value added products. Bamboo plantation provide direct employment, self-employment and secondary employment based on forest products. Direct employment is provided in the form of managerial, technical, research, planning and executive jobs. It has been estimated than, one hectare of bamboo plantation with 500 clumps will generate 383.9 mandays of employment for unskilled labour and 47.3 mandays for supervisory and skilled labour over a period of 30 years. (Tewari 1992).

It has also been estimated that 17 mandays will be required to harvest, extract and transport one ADMT (Air duty Metric Tonne) of bamboos (Misra and Susaeta, 1973).

Self employment is generated when individuals are employed in production process whose output (or) benefits is, wholly (or) partly consumed by them. Removal of bamboo headlands, grazing in bamboo forests, lopping it for fodder (or) thatching purposes, availing of right and concessions are some of the activities which give self employment to the people.

Cottage industries which is based on bamboo such as , pulp and paper, paper board and rayon industries provide secondary employment to the people.

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BAMBOOS FOR COMMUNITY FORESTRY PROGRAMME

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ABSTRACT

Bamboo is integral to the culture of South-East Asia. Over 75 genera and 1250 species are reported to occur in the globe. India perhaps has the world's richest diversity of bamboo, claiming about 130 species occurring over an area of 9.57 million ha. This is about 12.8 percent of the total forest area of the country. The bamboo diversity in natural habitat is dwindling, due to over exploitation shifting cultivation practices and extensive forest fires. A sustained availability can be ensured only by elaborate bamboo cultivation through community forestry programmes based upon growing trees on public (a) community land as opposed to private farms. The degree of local participation in planting and looking after the trees varies, and the benefits are shared by community as a whole. The methods in raising bamboo plantations through community forestry suggested . Advantages in raising bamboo plantations in rural economy are discussed.

INTRODUCTION

Bamboos are giant, woody, tree- like- grasses with a long history as an exceptionally versatile and widely used resource. Bamboo is a cultural feature of South and Southeast Asia. No country in the region

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is without an indigenous bamboo flora. Its plethora of essential uses has led to the use of terms such as the "poor man's timber", the cradle to coffin plant, "green –gold", bamboo friend of the people and it still provides the material needed for the existence. Yet over-exploitation associated with growing human populations, destruction of tropical forests and new demands on the resources for industrial uses, especially by the pulp and paper industry, has resulted in wide scale decimation of bamboo stocks. Compared with the vast forests of the bamboo found in South and Southeast Asia at the beginning of this century, we are left with the current situation of acute scarcity. Efforts are therefore underway research into cultural and agronomic techniques which will boost bamboo production. (Shanmughavel 1995). So, the forest department can include bamboo as an important species for the community forestry programmes. In this paper an attempt, has been made to justify, bamboo can be successfully raised by community forestry programmes.

COMMUNITY FORESTRY PROGRAMMES

Community forestry programmes are based upon growing trees on public (or) community land as opposed to private farms. The degree of local participation in planting and looking after the trees varies. What all community programmes have in common, is that they are intended to provide benefits which are shared by the community as a whole.

The most common type of community-forestry programmes is that in which the forest department takes on the responsibility for carrying out the planting. Inputs such as fertilizers and seedlings are provided without any outlay by the community. The engagement of the local community in the implementation of the schemes of this type is largely passive and is normally restricted to the provision of hired labour for planting and an agreement to co-operate in protecting the plantation.

Other programmes rely on a much higher level of community participation and control. They are generally designed to use land, which is under direct community ownership; (or) they can take place on state lands, which have been specially designated for community control. The main responsibility for planting and looking after the trees is taken by community itself and the role of the promoting agency is primarily a catalytic one. Community programmes can use both commercial and non-commercial incentives as a way of stimulating local participation. In all cases, the key to success lies in persuading local people that the programme is in their interests as that the benefits they are promised are securely guaranteed.

GUIDELINES TO RAISE BAMBOO PLANTATIONS

By far the single-most important item of forest produce used by rural communities of the tropics, from the cradle to the coffin, is the bamboo. Over 75 genera and 1250 are reported to occur in the world. The demand for this material has increased for beyond the availability, causing serious problems of over-exploitation and depletion of resources. Cultivation of bamboo can provide a cost effective return within short term (3 years). To increase the pace of greening the country and in the alleviation of poverty it expedient to evolve an appropriate technology for successful raising bamboo plantations at economical costs, through community forestry.

The methods of successful raising of bamboo plantations are as follows.

PREPARATION OF NURSERY

Nursery beds of 10 x 5m were prepared in the field and filled with a mixture of soil and sand (3:1). The seedlings (*Bambusa bambos*) when about 7 cm in height were picked out from the polythene bags. (Seedlings from the tissue culture methods were obtained, since bamboo seeds possess very short period of viability). About 15-25 seedlings were planted in $1m^2$ of raised nursery beds. (one week prior planting, the nursery bed were drenched with 0.01% aldrex and 0.05% bavistin to prevent termite and fungal attack respectively). Watering was done 2-3 times a day. Care was taken to avoid over saturation. Nursery beds were provided with a thatch to protect the seedling from direct sunlight.

TRANSPLANTING

The seedlings in the nursery were uprooted carefully and transplanted to 45 x 45 cm pit in the fields, before the onset of monsoon. The seedlings were planted with 6m x 6m spacing in 3 ha area with 250 seedlings/ha. To provide better initial growing environment to the seedlings, the upper halves of the pits were filled up with a mixture of 25 gram of complex (17:17:17) per pit, while lower halves were filled up with the original soil. The transplanted seedlings were watered two hours regularly in the morning and evening. Weeding was done as and when required. After one year, the plantation was adequately irrigated with 15 days interval. Protection against damage by rodents, grazing and browsing animals were provided by prushwood fence.

GROWTH AND PRODUCTION OF CULMS

All the transplanted seedlings produced rhizomes. The culm buds emerge with the onset of early rains and grows rapidly. The total number of culms in 1st, 2nd, 3rd, 4th, 5th and 6th years old clump/ha was 1250, 2250, 3000, 3500, 4000 and 4250 respectively. The culm height in 1st year was 1.4 m, 3.2m in 2nd year, 9.6 m in 3rd year, 21.8m in 4th year, 27.2 m in 5th year and 28.5 m in 6th year. Their corresponding diameters at different ages were 2.3 cm, 3.3 cm, 4.3 cm, 4.8cm, 6.3cm, and 8.3cm, respectively. An unusual rain during winter months may induce the emergence of new culms but they do not grow successfully, like those produced in the rainy season. The productivity of new culms mostly depend on the degree of congestion, clump age and rainfall of the previous year. It was noticed that annual recruitment of culms increased proportionately with age (Table-60) **(Where is table 60)**.

PROCESS OF GROWING

The appearance of the culm was very slender and the growth of sprout was slow in the beginning. It gradually began to grow faster till the culm reached maximum and seized thereafter. The daily average growth height of the culm was approximately 30 cm. Till, 32nd day the internodes were wrapped with sheaths and thereafter during the 1st month the culms lost their sheaths. After 50 days, branch buds began to develop. These branch buds increased two to three in number in a circle and were clearly visible after 60 days. Their length began to increase upto 30 days (i.e. 90 days after their emergence), after which leaf buds began to appear on their nodes alternately. These leaves began to mature in the subsequently 30 days of their visual appearance. They varied their length from 15-20cm and were simple long leaves. The leaves attained their full development around 135th day. Thereafter the culms began to change their hardness and colour. The new culms were produced peripherally from the outer edge of the clump and tended to grow inwards and get entangled among the older culms.

DEGREE OF LOCAL PARTICIPATION

As discussed earlier, the aim of community forestry programmes are to regenerate the degraded forests and barren lands.

(a) Local Institutions

Community tree growing programmes are crucially dependent upon the active collaboration of village councils, community groups (or) other local institutions. Programme planning must therefore, be based upon a clear appreciation of actual role, such organizations plays in local affairs, their potential for realizing (or) thwarting the aims of the programme. The village community groups should be trained (or) giving proper instructions, about the growing of bamboo in the barren land by the specialists in the field. While selecting the village community groups, preference will be given only to the educated unemployed youths.

(b) Land Allocation

Maximum 25 ha area of degraded / barren forest land is to be allocated at a time to each participating village group. In future, more land can be allocated if the work of the participating village committee is found encouraging.

(c) Procedure of Working

After collaborative micro-planning, a need-based management plan will be drawn up. The forest department will assist the village committee to establish joint protection and management systems.

(d) Requirements / Rule of Working

Order requires participating village committees to project the allocated land against non-forestry use, encroachments, grazing, illicit-felling and wildlife. Land in no case is to allocated to individuals and ownership of the land shall remain with the Government. It is also required to execute an agreement bond-between forest officials and the participating village committee.

(e) Resource Sharing

Entire bamboos obtained from community forestry programmes will go the members of the participating village committee. At the time of harvest prescribed in the management plan, after deducting the government expenditure, 60 percent share of net income will go to the members of the participating village committee and 40 percent share to the state exchequer. Participating village committee will again invest atleast 50 per cent of this income in plantation activities.

(c) Monitoring of Works

A supervisory committee is to be constituted to monitor the development, protection and management works of the community forestry. Members of the committee will include respective district forest officer, a range officer, and a representative of village committee members.

LIMITATIONS

(a) The problem of land- use conflicts

Obtaining the necessary land for tree growing is undoubtedly one of the major stumbling blocks in programmes of this type. Community land is frequently scarce, (or) is being used for a variety of other purposes. Agreement to dedicate it to a tree growing can be very difficult to achieve.

(b) Lack of identity of interests

Few communities have a genuine identity of interests among all their members. Practical experience has shown that this can cause a number of severe problems with community programs, where communities are rigidly stratified along social, economic (or) religious lines, the barriers to communal action can be partially difficult to over come.

ADVANTAGTES IN RAISING BAMBOO PLANTATIONS

The details of simple economic analysis of cost and benefit of *Bambusa bambos* plantations are presented in Table 61. It can be concluded that the establishment of Bamboo plantation is not profitable at the end of three years. However, after this period, it is noticed that cost benefit (B/C) ratio exceed 1.0 showing very good financial results. (Shanmughavel and Francis 1993).

SCOPE FOR COMMUNITY FORESTRY

The interest complexity of Community forestry programmes, with their needs for compromise and reconciliation of opposing interests, means that they will always require a great deal of careful preparation and negotiation. This demands a high level of trust and co-operation between the community, and the promoting agency which can, itself take a long time to create.

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Preliminary Study of Regeneration Pattern of the Forest Tree Species

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Introduction : The importance and influence of natural disturbances on the structure and dynamics of biological communities have been emphasized by many workers [1-6]. The magnitude of the disturbances can be assessed by analysing the population size, class structure at the stand which also conveys the information on its regeneration behaviour, successional status and pattern of forest dynamics [1]. Keeping this in view, a preliminary study was carried out to determine the extent of biotic and natural disturbances and their impacts on vegetation structure and regeneration potential of some important forest trees at Thalamalai range, in Sathyamangalam Forest Division.

Material and Methods

Study Site : The forests are located between 11° 28′ to 12° N lat. and 76° 50′ to 77° 47′ E long. It is approximately 590 m above the mean sea level. On the basis of preliminary reconnaissance seven sites (Chickally, Kulkends, Kudubai, Kumbaswara Koil, Kobbaikatta,- Kundukalmade and Chithrikarai) were selected for the analysis of forest.

Climate : The meteorological data of Thalamalai range indicating that the mean minimum and maximum temperature is 80°C and 74°C respectively. The mean humidity varied from 56 per cent to 80 per cent. .The mean monthly rainfall ranged between 30 mm to 640 mm during 1992-93. Annual rainfall averages at 1600 mm. Severe wind blowing during south-west monsoon. Mostly red soils are found in the range.

Vegetation Analysis : Reconnaissance survey of studying the tree communities are applied to the study area. A straight line survey was made and tree vegetation recorded along the line of travel only. The trees affected by wild animals (or) due to fire were marked with paints, during the year June 1992. Parallel lines were also taken into account when sufficient observation are not available. After one year the pattern and extent of regeneration were studied.

Results and Discussion : The trees found in each area and their regeneration potential are presented in Table 1. It reveals that mostly the disturbances to the tree communities are caused by wild animals and fires. It was observed that the buds sprout during the rainy season. All the regenerated trees showed coppice system of natural

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Table 1. Natural regeneration pattern of forest trees.

Place (Thalamalai Range)	Trees found in the study area	Influence of natural disturbance	Type of regeneration
Chickally	*Bambusa bambos* (L.), *Acacia nilotica* Willd.	Fire, wild animals	By rhizomes and coppice
Kulkonda	*Albizia lebbeck* (L.) Benth. *Acacia sinuata* (L.) Merr.	Wild animals	Coppice No regeneration
Kudubai	*Acacia nilotica* Willd., *Bauhinia racemosa* Lam., *Phyllanthus emblica* L.	Fire, wild animal	Coppice Coppice No regeneration
Kumbeswara Koil	*Acacia sinuata* (L.) Merr. *Acacia leucophloea* (Roxb.) Willd. *Albizia odoratissima* L.A. Benth.	Fire, wild animal	No regeneration Coppice Coppice
Kebbaikatta	*Tamarindus indica* (L.) *Bambusa bambos* (L.) *Albizia lebbeck* (L.) Benth.	Fire, wild animal	No regeneration By rhizone Coppice
Kundukalmadu	*Acacia leucophloea* (Roxb.) Willd. *Albizia odoratissima* (L.A.) Benth. *Acacia nilotica* Willd. *Phyllanthus emblica* L.	Fire, wild animal	Coppice Coppice Coppice No regeneration
Chithrikarai	*Acacia leucophloea* (Roxb.) Willd. *Acacia sinuata* (L.) Merr. *Albizia lebbeck* (L.) Benth. *Bauhinia racemosa* Lam.	Fire, wild animal	Coppice No regeneration Coppice Coppice

regeneration. The regeneration potential of *Albizia lebbeck*, *Albizia odoratissima*, *Acacia leucophloea* and *Bauhinia racemosa* has been found better by producing increased number of lengthy branches. Whereas in *Acacia nilotica*, the newly sprouted branches were found to be shorter in length. In *Bambusa bambos* number of new culms produced were lesser, and shorter in length and narrow in diameter. So, it has been concluded that, the biotic disturbances considerably reduced the growth characteristics of forest trees, thereby reduced the timber value. *Acacia sinuata*, *Azadirachta indica*, *Phyllanthus emblica* and *Tamarindus indica* did not show any regeneration. In general, the biotic disturbances modifying the forest canopy structure. Hence further detailed study is suggested to improve the natural regeneration of forests so as to preserve the forest trees from the biotic and natural disturbances.

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Short Communication

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THE EFFECT OF FIRE ON *BAMBUSA BAMBOS* IN FORESTS OF SATHYAMANGALAM, TAMIL NADU

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The effects of fire on *Bambusa bambos* in forests of Sathyamangalam were studied from December 1992 to November 1993. The results reveal that, recruitment of annual culms, growth characteristics and accumulation of biomass were found maximum in control grove over partially burnt and completely burnt groves. The fire significantly reduced the growth of all the parameters studied.

The fire is a natural calamity for forest values. Every year hundreds of trees are either totally burnt or damaged partially in wild fires. Fire has a significant effect in shaping the structure and composition of forest vegetation. The forest fires are almost common phenomena in forests of Sathyamangalam. Studies on the effect of fire on the forest vegetation structure at Sathyamangalam forests are very meagre (Shanmughavel & Raveendran 1993) However, the effect of fire on Bamboo groves in this locality are not cited in literature. In order to evaluate the effect of fire on bamboo, on new culm recruitments, and annual productivity an experiment was taken up at Iruttipalayam, in the forests of Sathyamangalam, Tamilnadu.

The study area is situated near Iruttipalayam, about 32 km from Sathyamangalam. The forests are located between 11° 28 to 12° let, 76° 50 to 77° 47 E long. It is approximately 1150 m above the mean sea level. The climate of the area is monsoonic. A total of three bamboo groves with similar climatic and edaphic conditions were taken for this study. The bamboo grove not effected by fire was taken as control. One partially burnt grove and another completely burnt grove were also taken for this study. The total number of culms present in each grove, their average height and diameter (DBH) were recorded in the beginning of the experiment (Table 1). The observation were continued for one year, to study the annual recruitment of culm, growth characteristics, and accumulation of biomass. To study the organic productivity of components of Bamboo, in each grove five culms were brought to the laboratory, dried to constant weight at 80°C and the dry weights recorded.

Table 1: Growth characters of Bambusa bambos at the beginning of the experiment

S. No.	Type of Bamboo Groove	Number of Culms/ Grove	Average Height (m)	DBH (cm)
1.	Control	45	17 ± 0.41	6.5 ± 0.40
2.	Partially burnt	19	16 ± 0.33	6.5 ± 0.24
3.	Completely burnt	0	-	-

(± Standard deviation)

In the study area, natural forests fires are common during summer season. Sometimes if the intensity of fire is severe, most of the bamboo groves are completely burnt. Similar type of total elimination of vegetation was observed in bamboo in many parts of Central India, by Lal (1990) and in *Tephrosia purpurea* species in forests of Sathyamangalam by Shanmughavel & Raveendran (1993).

The productivity of bamboo is assessed by the number of culms produced annually. The growth characteristics such as annual recruitment of culms, average height and diameter were analysed in fire affected grove and control grove (Table 2). It reveals that annual recruitment of culms was found higher in control in comparison with partially burnt and completely burnt

Table 2: Effect fire on growth characteristics of Bambusa bambos

S. No.	Type of Bamboo Grove	Annual Recruitment of culm	Average Height (m)	DBH (cm)
1.	Control	13	18.5 ± 0.52	8.5 ± 0.41
2.	Partially burnt	8/4*	17.0 ± 0.41/ 8 ± 0.40*	3.5 ± 0.20
3.	Completely burnt	5	6 ± 0.20	2.5 ± 0.10

Culm from fire affected parts. ± Standard deviation.

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Table 3: Effect of fire on biomass* of Bambusa bambos

S. No.	Type of Bamboo grove	Biomass Components (kg/culm) Culm	Branch	Leaf
1.	Control	23.0	8.700	0.840
2.	Partially burnt	21/3.5*	6.800/ 1.200*	0.570/ 0.340*
3.	Completely burnt	3.4	1.100	0.270

*Culms from fire affected parts.
*Average of five culms.

grove. It was found that in control sprouting of new culms produced along the outside of the culms, they often tend to grow inwards, to get entangled among the older culms. Also the culms produced were taller and bigger in diameter. On the other hand, in partially burnt grove, unaffected part produced culm similar to that of control, where as the fire affected parts produced culms of comparatively shorter and smaller diameter. In completely burnt grove, sprouting of new culms took place anywhere in rhizome and fire significantly reduces all the growth characteristics. The effect of fire on biomass components (culm, branch and leaf) are presented in Table 3. The maximum accumulation of biomass in all components was observed in control grove rather in the fire affected grove. In this study it is clear that fire considerably reduced the productivity of bamboos. But in other species forest fire enhances the productivity, by sprouting of higher number of branches in the fire effected parts in *Grewia tilifolia* (Shanmughavel & Raveendran 1993), and by increasing the quantity of natural regeneration in *Acacia mollissima* (Venkataramani 1964).

It is said that, the dried bamboos become a potential fire hazard, during summer season. In the event of fire in dried bamboo areas, the spread of fire is so fast that, it would not normally be possible to suppress the fire. Under such circumstances either fire protects measures are to be greatly intensified (or) the dead material was to be removed in order to reduce the fire hazard.

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Short Communication

A Case Study of Traditional Bamboo Workers in Sathyamangalam Taluk, Tamilnadu

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Bamboo is the most versatile forest product in Sathyamangalam forests. It is used by the traditional bamboo workers in this area from times immemorial for a veriety of purposes. High strength to weight ratio, easy workability and comparative cheapness together with availability in abundance and short period of maturity are the reasons of its popularity [1]. It continues to hold an important place in the rural economy of the developing countries especially in the Asia and Pacific region [3, 4].In Sathyamangalam Taluk, the traditional bamboo workers belong to the economically weaker and socially backward strata of the society. Weaving pedels and baskets using bamboo is a traditional occupation of these people. After collecting the raw material from the nearby forests, they manufacture pedels and baskets in their houses and later sell them in the local markets or households. In this paper, the problems and some socio-economic conditions of bamboo workers are discussed. The results of the study will indicate the appropriate measures for improving the availability of raw materials for bamboo workers in producing bamboo based products.

Material and Methods : Data was collected from hundred traditional bamboo workers of Sathyamangalam Taluk. Sathyamangalam, Chikkarasampalayam, Vadavalli, Kembanaickenpalayam and Kallipatty areas were selected for the study. A sample survey was conducted to ascertain the problems and socio-economic constraints of the bamboo workers and the extent to which the present structure helps them to improve their living conditions. In each place, twenty persons (both men and women) were questioned and the data recorded. The major socio-economic variables examined were caste, literacy and income groups [2].

Results and Discussion : In the study area, the *Bambusa arundinacea* is widely used as a raw material for making baskets and other bamboo-wares. Sathyamangalam is famous for bamboo baskets owing to the expertise of the local people and the availability of the raw material. These bamboos are harvested from the neighbouring natural forests of Sathyamangalam. Generally

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harvesting of bamboo is not allowed by the Forest Department. According to bamboo workers, some persons knowingly or unknowingly harvest the bamboo and sell to them. The average cost of a 10 m long culm of *B. arundinacea* is about Rs. 6. Ist quality basket of 75 cm diameter and 60 cm height (7 numbers) requires about three culms. The time taken for weaving one basket is 1½ hours. One middle aged person can make as many as four baskets a day. The net income one can get is Rs. 20, to Rs. 40 per day. Five second quality baskets can also be made from the remaining bamboo strips. The monthly income of bamboo worker in this taluk varies from Rs. 400 to above Rs. 600/-.

Baskets used for domestic and other purposes and containers can be made by these bamboo workers. Their size and shape and fineness are dependent on the end use and market demands. The big and coarse varieties are used for packing vegetables, fruits, fish and other agricultural produce, while small and fine quality are used as hand-carrying baskets. The bamboo basket makers face serious problems, such as the increasing price of raw material, non-availability of raw materials and competition from substitute materials. Some of them want to give up basket making but have no alternatives. Although income from basket making is rather small but they have no alternative resources of their livelihood.

The traditional bamboo workers in the study area belong to Vellalagounder, Kuravar and Valluvar communities (Table 1). The average size of the family ranges from 4-6 members and a majority of them are involved in the processing of bamboo either in its harvesting or in weaving. The highest literacy rate was found in Sathyamangalam, followed by Chikkarasampalayam, Kembanaickenpalayam, Vadavalli and Kallipatty respectively (Table 2). The distribution of bamboo workers according to monthly income groups are presented in Table 3. It is understood that social backwardness seems to go along with economic backwardness. The survey has shown that the children of the bamboo workers were less educated (or) illiterate. For them, employment opportunities in alternative spheres were negligible. Many of the sample workers expressed their views in favour of setting up of Bamboo Co-operative Societies in Sathyamangalam Taluk.

Table 1. Distribution of bamboo workers according to caste.

Caste	Sathyamangalam	Chikkarasampalayam	Vadavalli	Kembanaickenpalayam	Kallipatty
Vellalagounder	11	8	4	6	4
Kuravar	6	10	9	9	11
Valluvar	3	2	7	5	5

Table 2. Distribution of bamboo workers according to educational status.

Status	Sathyaman-galam	Chikkarasa-mpalayam	Vadavalli	Kembanaic-kenpalayam	Kallipatty
Illiterate	3	—	1	8	6
Primary	2	15	17	8	14
Secondary	10	5	2	4	—

Table 3. Distribution of bamboo workers according to monthly income group.

Income (Rs)	Sathyaman-galayam	Chikkarasam-palayam	Vadavalli	Kembanaic kenpalayam	Kallipatty
400	2	3	—	—	2
400-500	4	5	9	10	4
500-600	10	10	7	5	8
600 & above	4	2	4	5	6

They indicated that the supply of raw material had been dwindling over the years which adversely affected their self-employment and income. Improvement in the living conditions of bamboo workers in Sathyamangalam Taluk can be brought about by providing employment opportunities and increasing supply of raw material at a subsidised rate.

Conclusion : From this study it is imperative that Bamboo Co-operative Society should be set up in Sathyamangalam at the earliest, so as to help improving the social and economical status of the bamboo workers in this area along with providing employment opportunities to the educated unemployed-youths of this area. Meanwhile necessary action is required to be taken for supply of raw materials to the bamboo workers through the Large Scale Multipurpose Co-operative Societies (LAMPS) with its headquarters located at Sathyamangalam. The results from the studies can be used as guideline for the improvement of bamboo-resource utilization in Sathyamangalam Taluk as well as for improvement of income distribution among the bamboo workers.

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GROWTH PERFORMANCE AND ECONOMIC RETURNS OF PIGEON PEA IN AGROFORESTRY

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Abstract

The growth performances and economic returns of Pigeon pea (*Cajanus cajan*) growing as intercrop in bamboo plantations are discussed. Pigeon pea intercropped in 1:1 rows at 3 m x 3 m spacing (250 plants/ha) and in 1:2 rows at 2 m x 2 m spacing (500 plants /ha) in bamboo plantations. The results of investigation indicated that on annual basis a net amount of Rs. 7900/- (2 m x 2 m) and Rs. 13,390 (3 m x 3 m) can be obtained. This agrisilviculture model provides food, fuel, fodder and timber to rural population.

Introduction

Agroforestry is a collective name for all land use systems and practices, where woody perennials are deliberately grown on the same land management unit as agricultural crops (or) animals in some form of spatial arrangement (or) temporal sequence (Nair, 1989). Although considerable research has been under taken on industrial plantations, Community wood lots, alley farming, etc. (Nada Gounda *et al.*, 1997; Sharma & Gulati, 1997 & Shanmughavel, 1995), information on the economics of farm forestry, especially the small plantations that are established by the individual farmers for the production of poles, fuel, fodder are very much limited (Balaji, 1991; Gupta & Mohan, 1982; Raiptree & Hoskins, 1990 and Reddy, 1988). The products meet the farmer's own needs and the surplus is sold in the market. The trees are primarily grown by the farmers to meet the requirement of small timber as well as soil conservation and improvement. In the present article results of the studies carried out on the growth performance of Pigeon pea and the economic returns by growing the species as intercrop in bamboo plantations are discussed.

Materials and Methods

Study Area : The study area is located at Kallipatty, Tamil Nadu State, India, between 11° 28' and 12°N latitude and 76° 59' and 77° 47'E longitude. Its altitude is 540 m asl. This area has red soil, with pH between 7.4 and 7.8, soil Nitrogen, Phosphorus and Potassium were 3800 kg/tha, 360 kg/tha, 3600 kg/tha respectively. The mean temperature is 31°C. Mean rainfall is 600 mm.

Bamboo Plantations : The seedlings of *Bambusa bambos* were planted with 6 m x 6 m spacing in 3 ha area with 250 seedlings/ha. Almost every seedlings produced culms, during the next year of transplantation. Since then culms were treated as one year old. On an average 5 culms emerged in the first year, gradually increased in subsequent years to 8, 12, 14, 16, 13, 11, 9, 8, 6 per clump. Culms emerging in the first year were short (1.4 m) in length and small in diameter (2.3 cm dbh). Culms produced in subsequent years were distinctly taller and thicker up to 6 years. After this period, a decline in both height and dbh was noticed.

Intercropping (Pigeon pea) : Intercropping of Pigeon pea in the established bamboo plantation was tried. Pigeon pea (*Cajanus cajan*) is a hardy pulse of tropical grassland and arid regions. It accounts for about 4% of the total pulse production in the World. The crop usually prefers a fairly moist climate during the period of its vegetative development. The crop may be grown in all kinds of soils, but it prefers a light and moist soil in which the roots can develop freely. ICPL-88034- an extra

short duration Pigeon pea (10 months duration) was sown in bamboo plantations 1:1 rows at 3 m x 3 m spacing (density 250 plants/ha) and 1:2 rows at 2 m x 2 m spacing (density 500 plants/ha). The study on economic returns of agricultural crop was carried out after the first harvest.

Results and Discussion

Yield and returns from Pigeon pea : Information on the productivity of agricultural crops grown under the plantations in India in very limited and there is a high demand for the products of both agriculture and forestry. Since the density of Pigeon pea was 500 plants/ha at 2 m x 2 m spacing and 250 plants/ ha at 3 m x 3 m spacing, it was found that, 600 kg and 700 kg of grain yield was obtained from one hectare respectively. Details on the expenditure for growing and harvesting, etc., and income obtained are given in Table-1.

The net income from Pigeon pea interplanted with bamboos amounted to Rs. 7,900/- (2 m spacing) and Rs. 13,300/- (3 m spacing) at one year of age. Subsequent harvesting can be done after 6 months period of time, so some more revenue can also be obtained. Taking all these into consideration, the intercropping of Pigeon pea in the bamboo plantations at the espacement of 3 m x 3 m can be recommended to farmers.

Sowing of pigeon pea as intercrop has the following advantages:

1. It matures within eight months after sowing and avoids competition for light, moisture and nutrients with bamboo.
2. The variety minimizes yield losses due to the pest Heliothis.
3. However, a prophylactic spray with neem oil at 2.5 ml/l of water before flowering followed by monocrotophs at 1.5 ml/l of water at flowering may be needed.

Therefore there is a great need to indentify the suitable agricultural and horticultural crops, which can grow well with the tree plantations with limited solar energy avaiable.

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Table-1: Economic returns of Pigeon pea in agroforestry

	Details	Site - I (2 m x 2 m) spacing (Density 500 plants/ha)	Site - II (3 m x 3 m) spacing (Density 250 plants/ha)
EXPENDITURE :			
1.	Preparation of land, pitting soil mixture, planting, soil working, casually replacement etc., (up to 24 months)	Rs. 4, 000	Rs. 2,000
2.	Harvesting, processing and stocking	Rs. 2,000	Rs. 1, 000
3.	Other maintenance	Rs. 500	Rs. 500
4.	Total expenditure	Rs. 6, 500	Rs. 3, 500
INCOME :			
1.	Grain yield (in kg)	600	700
2.	Cost (Rs. 24/kg)	Rs. 14,400	Rs. 16,800
3.	Total Income	Rs. 14,400	Rs. 16,800
4.	Total Expenditure	Rs. 6,500	Rs. 3,500
5.	Net Income/Rs./ha/yr.	Rs. 7,900	Rs. 13,300

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REVIEW

FLORA OF THE DISTRICT GARHWAL NORTH WEST HIMALAYA

(With Ethnobotanical Notes) by **R.D. GAUR** pp. I-XII; 811, Map 1, 1999. Trans Media, Srinagar, U.P.

Price : Rs. 1600/-

With accumulation of our knowledge on Indian flora accrued during this century, it has become nearly impossible for any one to describe it in details as was done by Sir J.D. Hooker in the last century. So Indian Botanists in the last quarter of this century concentrated on modern studies of regional floras and the Flora of the District Garhwal North West Himalaya is therefore a step forward in this direction.

The present book includes about 1350 species (inclusive of 115 cultigens) falling under 978 genera from 189 families of flowering plants. The families have been treated according to Cronquist's System of Classification with little modification. The book has been divided into 8 chapters. The first five chapters provide useful information on geographical features, soils, climate, native inhabitants, vegetation types, besides review of floristic explorations and synoptic account of the flora of area of work, whereas, the last three chapters deal with keys, floristic account and selected references under bibliography.

Key to the families, genera and species are comprehensive and taxonomic delineation and descriptions are exhaustive which compensate for lack of any illustration or photographs in the book. The Vernacular/Hindi names and their equivalent available Sanskrit and English names, phenological data, ecological and ethnobotanical notes provided with each species, besides Index to Botanical, Vernacular/Hindi, Sanskrit, English names make the book most handy and immensely useful.

There can be no doubt that this book will find a wide readership amongst botanists, environmentalists, foresters concerned with the use, utility and conservation of Himalayan plants and research students in particular engaged in the floristic studies of NW Himalaya. The book is an welcome addition on district floras and fills the gap in our knowledge on this score.

The get up of the book is excellent with hard green cover and lovely colourful jacket. All this in Rs. 1600/- is not high by any standards.

B.K.GUPTA

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INTERCROPPING OF SOYBEAN (*GLYCINE MAX*) IN BAMBOO PLANTATIONS

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Abstract

The growth performances and economic returns of Soybean (*Glycine max*) growing as intercrop in bamboo plantations are discussed. Soybean intercropped in 1:1 rows at 3 x 3 m spacing with 1111 plants per ha, out of which only 35% of plants were established. Productivity of Soybean in the intercropped stand was found to be lower (1400 kg/ha.) compared with pure Soybean plantation (1700 kg/ha.). Similar results were observed in Bamboo. The land equivalent ratio (LER) of bamboo producing culms (dry weight) with Soybean intercrop found in the ratio of 1:2. The results of the investigations indicated that on an annual basis a net amount of Rs. 8300/= can be obtained. It can be recommended that Soybean may be grown as intercrop in the initial stages of bamboo plantations over red lateritic soils in tropics.

Introduction

Agroforestry means practice of agriculture and forestry on the same piece of land. In India bamboo plantations has been raised extensively to meet the increasing demand of the bamboo products (Tewari, 1994). Research has increased rapidly in recent years to cultivate agricultural crops on the espacement in bamboo plantations (Seshadri, 1985; Balaji, 1991; Shanmughavel and Francis, 1998). An attempt has been made to intercrop soybean (*Glycine max*) in the bamboo (*Bambusa bambos*) plantations. In the present article results of studies carried out on the growth performances of soybean and the economic returns by growing the species as intercrop in bamboo plantations have been discussed.

Materials and Methods

Study Area: The study area is located at Kallipatty, Tamil Nadu State, India, lies in between 11° 28' and 12° N latitude and 76° 59' and 77° 47' E longitude. Its altitude is 540 m a.m.s.l. This area has red soil with pH between 7.4 and 7.8. Soil nitrogen, phosphorus and potassium were 3800, 360 and 3600 kg per hectare respectively. The mean temperature and rain fall is 31°C and 600 mm respectively.

Bamboo plantations: The seedlings of *Bambusa bambos* were planted with 6 x 6 m spacing in 3 ha. with 250 seedlings per ha. Almost every seedling produced culms during the next year of transplantation. Since then culms were treated as one year old. On an average 5 culms emerged in the first year, gradually increased in subsequent years to 8, 12, 14, 16 and 18 per clump. Culms emerged in the first year were short (1.4 m) in length and small in diameter (2.3 cm dbh). Culms produced in subsequent years were distinctly taller and thicker for up to 6 years. After this period a decline in both height and dbh was noticed.

Intercropping (Soybean): Intercropping of Soybean in the bamboo plantation was tried. Soybean is one of the most important legume crop in the world. It may be grown under varying climatic conditions either as pure crop or as intercrop. The best results are obtained on fertile loam and sandy loam soils. M.A.C. S-58 variety of soybean (6 months duration) was sown in bamboo plantations 1:1 row at 3 x 3 m spacing (1111 plants per ha) during June. While intercropping only 35% of plants could establish themselves. The study on growth and economic returns of Soybean crop was worked out after the harvest.

Results and Discussion

Yield and Return: The information on the productivity of agricultural crops grown under tree plantations in India is very limited and there is a high demand for the products of both agriculture and forestry. While sowing density of Soybean was 1111 plants per ha. but only 35% of plants could establish during intercropping. 1400 kg/ha of grain yield was recorded in this study (Table-1). However higher grain yield was obtained in Pure Soybean stand (1700 kg/ha). Production of culms and accumulation of above ground biomass in a pure and intercropped bamboo stand is presented in Table-2. It also revealed that the culm recruitment in pure bamboo stand was found higher (13 culms/clump) compared with intercropped stand (7 culms/clump). This may be due to the below ground competition for nutrients, water, etc. (Bowen, 1994).

Table-1: Yield of Soybean in pure and intercropped stand

Pure stand	Intercropped stand
Total number of Soybean planted = 1111/ha	1111/ha
Average yield obtained from single plant = 1.53 kg	1.26 kg
Yield per hectare = 1700 kg	1400 kg

Table-2: Economic returns of Soybean in agroforestry

Details	Soybean in agroforestry (Rupees)
Expenditure	
1. Preparation of land, pitting soil mixture, planting, soil working, casual replacement, etc., (up to 10 months).	Rs. 3000
2. Harvesting, processing and stocking.	Rs. 1100
3. Other maintenance.	Rs. 200
Total expenditure.	Rs. 4300
Income	
1. Grain yield (kg)	1400
2. Cost per kg	Rs. 9/=
3. Total income	Rs. 12600
Total expenditure	Rs. 4300
Net gain income in Rupees per ha per year	Rs. 8300

Land Equivalent Ratio (LER)

The land equivalent ratio of bamboo producing culms with Soybean intercrop showed that:

Sole Soybean	Sole Bamboo	Intercropping
1700 kg/ha	36.23 kg/ha 14.35 kg/ha	1400 kg/ha

The LER of the system = 1400/1700 + 14.35/36.23

= 0.82 + 0.39 = 1.21

This means that the productivity of one hectare under intercropping is equivalent to that of 1.2 hectares under the sole system.

Details on the expenditure for growing and harvesting, etc., and income obtained are presented in Table-3. The perusal of table revealed that the net income from Soybean interplanted with bamboo amounted to Rs. 8300/= after the harvest. From the results it can be concluded that Soybean may be planted in the initial stages of the bamboo plantations.

Table-3: Production of culms and the accumulation of above ground biomass in a pure and intercropped stand of bamboo

Pure stand			Intercropped stand
Average production of culms/clump/year	=	13	7
Total number of clumps per hectare	=	250	250
Culm production per hectare	=	3250	1750
Average above ground biomass per culm	=	11.15 kg.	8.2 kg.
Total accumulation of above ground biomass	=	36.237 kg/ha	14.350 kg/ha.

Acknowledgement

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INTERCROPPING OF TURMERIC (*CURCUMA LONGA*) IN BAMBOO PLANTATIONS

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Abstract

This paper presents the results of intercropping trials of turmeric (*Curcuma longa*) in the bamboo plantations using randomized complete block design. Productivity of turmeric in the intercropped stand was found to be lower (13.3 t/ha.) compared with raising (19.1 t/ha.) sole turmeric plantations. Similar results are observed in the bamboo stands. However, the land equivalent ratio of bamboo producing culms with turmeric intercrop found in the ratio of 1:2 and therefore suggested that turmeric can be recommended as an intercrop in the bamboo plantation.

Introduction

Agroforestry is an alternative land use system under the situation of shortages for fuel, fodder and timber where no separate land is available to increase the area under forest. Bamboo is basically a household species and is the best friend of the farmers. In India, normally bamboo plantations are raised at the espacement of 6 x 6 m to meet the increasing demand of the bamboo products (Shanmughavel, 1995). Research efforts are increasingly being made in recent years to cultivate agricultural crops in the espacement in bamboo plantations (Balaji, 1991; Shanmughavel and Francis, 1998, 1999). In the present article, results on the intercropping of turmeric (*Curcuma longa*) carried in the bamboo plantations at Kallipatty (Tamil Nadu) are discussed.

Materials and Methods

Study site: The study site is located at Kallipatty, Tamil Nadu (India) and lies between 11°, 28" and 12° latitute and 76° 59" and 77° 47" longitude. Its altitute is 540 mean sea level. This area has red soil, with pH between 7.4 and 7.8. Soil nitrogen, phosphorus and potassium were 3800 kg/ha., 360 kg/ha. and 3600 kg/ha. respectively. The mean temperature and rainfall is 31°C and 600 mm respectively.

Bamboo plantations: The seedlings of *Bambusa bambos* were planted at 6 x 6 m spacing in 3 ha. at rate of 250 seedlings per ha. Almost every seedlings produced culms during the next year of transplantation. Since then the culms were treated as one year old. On an average 5 culms emerged in the first year, gradually increased in subsequent years to 17 per clump at the 6th year of age and then the culm recruitment decreased to 7 at the age of 10 years. In the plantations all the culms above three years were harvested. Pruning was done in the remaining culms.

Intercropping: Intercropping of rhizome of turmeric in the establishment of bamboo plantation was carried out. The crop requires a warm and moist climate, well drained, fertile, sandy to clayey soil, rich in humus and uniform in texture are considered highly suitable for its cultivation.

Experimental design: The experiment was laidout as a randomised complete block design with four replicates. The dimensions of the individual plots were 8 x 4 m. Of the four replications, one block was kept as control, whereas in the remaining three blocks an approximately 200 turmeric rhizomes were planted. For sowing both round and finger like, rhizomes were cut into 2.5 to 5 cm long pieces, each having at least one sound bud. The rhizomes were

planted 7.5 cm deep and 12.5 cm apart in either direction. The crop was sown in the month of April (first week). A pure turmeric plot planted as sole crop was kept as control. Harvesting of turmeric was done at the end of January.

Comparisons between different agroforestry system requires calculations of yield on a per ha. basis. While calculating either of bamboo or turmeric yield, if six metres of bamboo and four metres of turmeric are harvested, then the approximate harvest area is 24 m^{-2}. Conversion to a per ha. yield was made by multiplying the yield from 6 metres with 10000/24.

The land equivalent ratio is a convenient method to compare the biological productivity of these two arrangements by combining the two types of yield. It is defined as the land area in the sole system that would required to produce the same yield as one ha. of intercropping. It is calculated as follows:

$$LER = C1/Cs + T1/Ts$$

Where C1 and T1 are crop and tree yield under intercropping and Cs and Ts are yields in the sole system respectively (Rao and Coe, 1992).

Results and Discussion

Yield: In this study, the intercropped turmeric was harvested after ten months of planting. On an average of three replicates, the per ha. turmeric yield showed 0.160 kg (Table-1) while converting it to a hectare yield basis, the productivity is 13,344 kg/ha. However higher productivity of 19,182 kg/ha. was found in the sole turmeric plantation. Similar higher productivity in the sole plantation crop has also been reported in other studies (Shanmughavel and Francis, 1998, 1999; Balaji, 1991).

As in the agricultural crops, the culm recruitment of sole bamboo plantation was found higher. The average number of newly produced culms per clump of intercropped bamboo is only 8. However 11 culms/clump were recorded in the sole bamboo plantation (Table-2). This lower production of culms may be due to the below ground competition for nutrients, water, etc. Ultimately, unit area biomass accumulation found to be lower in the intercropped bamboo (12 t/ha.) compared with sole bamboo (24.7 t/ha.) plantation.

Table-1: Yield of turmeric in Pure and Intercropped Plantation

Intercropped turmeric :		
Total number of turmeric planted (unit area)	=	200
Average yield obtained from single turmeric plant	=	0.16
Productivity unit area (kg)	=	32.00
Yield per ha. (kg/ha.)	=	13.344
Pure turmeric :		
Total number of turmeric planted (unit area)	=	220
Yield obtained from single turmeric (kg)	=	0.21
Productivity unit area (kg)	=	46.00
Yield per hectare (kg/ha)	=	19.182

Table-2: Production of culms and accumulation of above ground biomass in pure and intercropped bamboo stand

	Pure stand	Inter-cropped
Average production of culms/clump/year	11	8
Total number of clumps per ha.	250	250
Culm production/ha.	2750	2000
Above ground biomass/culm	9	6
Total above ground biomass	24.75	12.0

Land Equivalent Ratio (LER): The land equivalent ratio of bamboo producing culms (dry weight) with turmeric intercrop showed:

Sole turmeric	Sole bamboo	Intercropping
19.1 t/ha.	24.7 t/ha.	13.3 t/ha. turmeric 12.0 t/ha. culms

$$\text{The land equivalent ratio of the system} = \frac{13.3}{19.1} + \frac{12.0}{24.7} = 1.2$$

This means that the productivity of one hectare under intercropping is equivalent to that of 1.2 hectares under the sole system.

The results of the study revealed that turmeric can be recommended for the intercropping of bamboo plantations and would be beneficial to farmers.

Acknowledgement

The first author is thankful to the CSIR, New Delhi for providing Research Associateship.

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20

INTER-CROPPING OF BAMBOO WITH GINGER

P SHANMUGHAVEL AND K. FRANCIS

AGRO forestry is an alternative land use system under the situation of shortages of fuel, fodder and timber with no separate land available to increase the area under forest to meet the requirements and to overcome the ill effects of degradation of natural forests (Nair *et al*, 1981). Bamboo is basically a household species and is the best friend of the farmers. The availability of natural bamboo resources have been decreased due to over exploitation, gregarious flowering, shifting cultivation practices and extensive forest fires (Tewari, 1995). The present crisis in the sustained availability can be ensured only by raising elaborate bamboo plantations (Shanmughavel, 1995). In India, normally bamboo plantation are raised at the escapement of 6 × 6 metres to meet the increasing demand of bamboo products. Research has increased rapidly in recent years to cultivate agricultural crops in the escapement in bamboo plantations (Seshadri, 1985; Balaji, 1991; Shanmughavel and Francis, 1998,1999). Therefore there is a great need to identity the suitable agricultural and horticultural crops, which can grow well with the tree plantation with limited solar energy available.

In the present study, inter-cropping of Ginger in the established bamboo plantations was tried. The growth, yield and land equivalent ratio (LER) of the agro forestry systems are discussed. Further, the interactions in agroforestry system can be grouped into above and below ground parameters. The above ground interaction investigated showed variable results from species to species (Sharma, 1991,1992,1995) but very little information is available on below-ground interaction (Sharma and Gulati, 1997). Therefore, the present investigation also aimed to assess the production of new culms in bamboo in agriculture model.

MATERIALS AND METHODS

Study Area

The study area is located at Kallipathy, Tamil Nadu State, India, and lies between 11° 28 and 12° latitude and 76° 59, and 77° 47 longitude. Its altitude is 540 metres above sea level. This

areas has red soil, with pH between 7.4 and 7.8. Soil nitrogen, phosphorus and potassium were 3,800 kg /ha, 360 kg/ha and 3,600 kg/ha, respectively. The mean temperature and rainfall is 31° C and 600 mm respectively.

Bamboo Plantations

The seedlings of *Bambusa bambos* were planted with 6m 4 × 6m spacing in three hectare area with 250 seedlings per hectare. Almost every seedling produced culms during the next year of transplantation. Since then the culms were treated as one year old. On an average, five culms emerged in the first year, gradually increased in subsequent years to 17 a clump at the sixth year of age and then the culm recruitment decreased to seven at the age of 10 years. In the plantations, all the culms above three years were harvested. Pruning was done in the remaining culms.

INTER-CROPPING

Ginger *(Zinger officinale)*

Ginger *(Zinger officinale)* belongs to the family Zingiberaceae. It is an important spice crop of humid tropics. Being a premier flavouring agent in culinary preparations and an ingredient of medicines, ginger enjoys immense popularity. It is a perennial herb and bears a large scaly rhizome. The stem attains a maximum height of 3 feet. Being a shade-loving plant, ginger is grown in association with a wide variety of trees (Jaswal *et al* 1993; Spices Board, 1995). Ginger rhizome bits were planted at 1 m × 2 m spacing (5,000 plants/ha), at 4 inches depth. The crop was sown in the month of May and only 30 per cent of plants were established.

In the inter-cropping trials, three replications were maintained and one block kept as control. All the trials, growth and yield studies were conducted after first harvesting. Production of culms and above-ground biomass of culms was also investigated as suggested by Shanmughavel, 1995.

Land Equivalent Ratio (LER)

The land equivalent ratio is a convenient method to compare the biological productivity of these two arrangements by combining the two types of yield. It is defined as the land area in the sole system that would be required to produce the same yield as one hectare of inter cropping. It is calculated as follows

$$LER = C1/C_s + T1/T_s$$

where C1 and T1 are crop and tree yield under inter-cropping and C_s and T_s are yields in the sole system respectively (Rao and Coe, 1992).

Culm Production Study

In the agri-silviculture model, a set of 15 clumps were selected randomly and marked with paint for the assessment of monthly production of culms. Every month, the number of newly sprouted culms and their survival were recorded. The observation continued for full one year.

RESULTS AND DISCUSSION

In all the agri-silviculture models, on an average of three replicates, the per plant yield of

TABLE 1
Growth and Yield of Pure and Inter-Cropped Agricultural Crops

	Ginger/Bamboo	
	Pure Stand	Inter-Cropped
Total number of plants planted (ha)	5,000	5,000
Average yield obtained from single plant (kg)	0.20	0.13
Yield/hectare	1,000	650

Values above are average of three replications.

TABLE 2
Production of Culms and Accumulation of Above-Ground Biomass in Pure and Inter-Cropped Bamboo Stands

Characters	Bamboo/Ginger	
	Pure	Inter-Cropped
Total number of clumps/hectare	250	250
Average annual production of culms/clump	14	9
Total culm production year/ha	3,500	2,250
Average above-ground biomass culms/kg	8.5	7.0
Total accumulation of above-ground biomass ha/kg	29,750	15,750

Values above are average of three replications.

TABLE 3
Land Equivalent Ratio of Agri-Silviculture
(Model Bamboo/Ginger)

Pure agricultural crop yield (kg/ha)	1,000
Pure bamboo crop yield (kg/ha)	29,750
Intercropping	
Agricultural crop yield (kg/ha)	650
Bamboo yield (kg/ha)	15,750
$LER = C_i/C_s + T_i + T_s$	$\frac{650}{1000} + \frac{15,7500}{29,750}$
Land equivalent ratio (LER)	1.1

pure ginger was found higher, when compared with inter-cropped stand. (Table 1).

Similar higher productivity in the sole plantation crops was reported by Seshadri, 1985; Balaji, 1991; and Shanmughavel and Frances, 1998,1999). The average annual recruitment of culms was found maximum in the pure bamboo stand when compared to inter-cropped bamboo stand. Underground root competition for moisture, nutrients and space in relatively more important

in agroforestry system than above-ground crown competition. The productivity of bamboo is assessed by the number of new culms produced annually. At a given site, the production of new culms mostly depended on the degree of congestion, clump age, rainfall of the previous year and the nature of competition by the inter-cropped agricultural crops, etc. (Seshadri, 1985; Shanmughavel, 1995). The average annual recruitment of culms is presented in Table 2. It revealed that the number of culms produced was considerably reduced in comparison with pure bamboo stands. This may be mainly due to the competition with the root system of agricultural crops (Bowan, 1984; Dwivedi, 1992). Ultimately, the unit area above-ground biomass accumulation was found to be lower in the inter-cropped bamboo stand compared with pure bamboo stand.

Land Equivalent Ratio (LER)

The land equivalent ratio is a convenient method to compare the biological productivity of these two arrangements by combining the yield of the two. It is defied as the land area in the sole (pure) system that would be required to produce the same yield as one hectare of inter-cropping. The land equivalent ratio (LER) of bamboo producing culms (dry-weight) with agricultural crops showed 1.1 in the bamboo/ginger model. This means that the productivity of one hectare under inter-cropping is equivalent to that of 1.1 hectares under the sole system.

The results of the study revealed that ginger can be recommended for the inter-cropping of bamboo plantation to the benefit of farmers.

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Intercropping trials of four crops in bamboo plantations

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Abstract—The growth, yield and land equivalent ratios were assessed for pigeon pea, soybean, turmeric and ginger intercropped with *Bambusa bambos*, in Tamil Nadu, India. Pigeon pea and soybean appear to provide most benefits in terms of productivity.

Key words: Bamboo plantations; pigeonpea; soybean; turmeric; ginger; yield; LER.

INTRODUCTION

Agroforestry is an alternative land use system under situations of shortages of fuel, fodder and timber where there is no separate land available to increase the area under forest to meet requirements. It also helps overcome the ill effects of degradation of natural forests [1]. Bamboo is basically a household species and is very useful to farmers. The availability of natural bamboo resources have decreased due to over exploitation, gregarious flowering, shifting cultivation practices and extensive forest fires [2]. The present crisis in sustained availability can be ensured only by raising elaborate bamboo plantations [3]. In India, bamboo plantations are normally raised at spacings of 6 × 6 m to meet the increasing demand for bamboo products. Research has increased rapidly in recent years to cultivate agricultural crops in bamboo plantations [4–7]. There is a great need to identity suitable agricultural and horticultural crops, which can grow well with bamboo in plantation conditions.

In the present study, intercropping of agricultural crops (pigeonpea, soybean, turmeric and ginger) in established bamboo plantations was tested. The growth, yield and land equivalent ratio (LER) of the agroforestry systems are discussed. The above ground interaction investigated showed variable results from species to species [8, 9] but little information is available on belowground interaction [10]. The present investigation aimed to assess this in relation to the production of new culms in bamboo.

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MATERIALS AND METHODS

The study area was located at Kallipathy, Tamil Nadu, India and lies between 11°28′, and 12° latitude and 76°59′, and 77°47′ longitude. Altitude was 540 metres above sea level. This area has red soil, with pH between 7.4 and 7.8. Soil nitrogen, phosphorus and potassium were 3800 kg/ha, 360 kg/ha and 3600 kg/ha respectively. The mean temperature and rainfall is 31°C and 600 mm, respectively.

Planting arrangements bamboo plantations

Seedlings of *Bambusa bambos* were planted at 6 × 6 m spacing in a 3 ha area with 250 seedlings per ha. Almost every seedling, produced culms during the first year of transplantation. On an average, 5 culms emerged in the first year, increasing to 17 at the 6th year and then culm recruitment decreased to 7 at 10 years. In the plantations, all culms above 3 years were harvested. Pruning was done on the remaining culms.

To estimate the total above ground biomass, three culms were randomly selected and felled. After felling, fresh weight was estimated in the field and sub-samples were brought to the laboratory and were oven dried at 103°C to a constant weight. From the oven dry weight of the sample, the total above ground biomass was calculated by multiplying the total number of bamboo's with the average dry weight of the sample.

Intercropping (design and installation). Intercropping was carried out using 4 diverse crops:

(1) Pigeonpea: (*Cajanus cajan*)

Pigeonpea (*Cajanus cajan*) is a hardy pulse of tropical grassland and arid regions. It accounts for about 4% of the total pulse production in the world. The crop usually prefers a fairly moist climate during its vegetative development. The crop prefers a light and moist soil in which the roots can develop freely. ICPL-88034, a short duration pigeonpea was sown in a bamboo plantation, 1 : 1 rows at 3 × 3 m spacing with 1111 plants/ha during June. Only 45% of plants established.

(2) Soybean: (*Glycine max*)

Soybean (*Glycine max*) may grow under varying climatic conditions either as a pure crop or as an intercrop. The best results are obtained on fertile loam and sandy loam soils. M.A.C.S 58 was sown in bamboo plantations 1 : 1 rows at 3 × 3 m spacing (1111 plants/ha) during June. Only 35% of plants established.

(3) Turmeric: (*Curcuma longa*)

Turmeric is obtained from the underground rhizome of the plant. The crop requires a warm and moist climate, and well drained fertile sandy or clayey, medium

black, red or alluvial loams. It is a shade loving plant and can be grown in association with a variety of trees [11]. For planting, both round and finger-like rhizomes are cut into a 3 to 4 cm long pieces, each having at least one sound bud. The rhizomes were planted at 1 × 2 m spacing (5000 plants/ha). The crop was sown in April. Only 40% of plants established.

(4) Ginger: (*Zingiber officinale*)

Ginger is an important spice crop of the humid tropics. Being a shade-loving plant, ginger is grown in association with a wide variety of trees [11]. Ginger rhizome bits were planted at 1 × 2 m spacing (5000 plants/ha). The crop was sown in May and only 30% of plants established.

In all the intercropping trials, three replicates were maintained and one block kept as a control. Growth and yield studies were conducted after first harvesting. Production of culms and above ground biomass of culms was also investigated.

Parameters emphasized

The land equivalent ratio (LER) is a convenient method for measuring biological productivity. It is defined as the land area in a monocropping system that would be required to produce the same yield as one ha of intercropping. It is calculated as follows

$$\mathrm{LER} = \mathrm{C1/CS} + \mathrm{T1/TS},$$

where C1 and T1 are crop and tree yields under intercropping and CS and TS are yields in the mono system respectively [12].

In the agrisilvicultural model, a set of 15 clumps was selected randomly and marked with paint for the assessment of monthly production of culms. Every month, the number of newly sprouted culms and their survival were recorded over a period of one full year.

RESULTS AND DISCUSSION

Based on one year of observations, the data in Table 1 show that, for all crops, yield in pure stands was higher then in intercropping models. This has also been reported previously [4–7].

The average annual recruitment of bamboo culms was found greatest in pure stands as compared to intercropped stands. Under ground root competition for moisture, nutrients and space are relatively more important factors in agroforestry systems than is above ground competition. The productivity of bamboo was assessed by the number of new culms produced annually. At a given site, the production of new culms mostly depended on the degree of congestion, clump age, rainfall of the previous year and the nature of competition.

Table 1.
Growth and yield of monoculture and intercropped agricultural crops

	Pigeonpea/bamboo		Soybean/bamboo		Turmeric/bamboo		Ginger/bamboo	
	Pure	Intercropped	Pure	Intercropped	Pure	Intercropped	Pure	Intercropped
Total number of plants planted (ha)	1111	1111	1111	1111	5000	5000	5000	5000
Average yield obtained form single plant (kg)	0.63	0.59	1.53	1.26	0.86	0.21	0.20	0.13
Yield/ha*	700	600	1700	1400	6050	4300	1000	650

* Values are means of three replicates.

Table 2.
Production of culms and the accumulation of above ground of biomass in monoculture and intercropped bamboo stands

	Bamboo/pigeonpea		Bamboo/soybean		Bamboo/turmeric		Bamboo/ginger	
	Pure	Intercropped	Pure	Intercropped	Pure	Intercropped	Pure	Intercropped
Total number of clumps/ha	250	250	250	250	250	250	250	250
Average annual production of culms/clump	17	10	13	7	11	8	147	9
Total culm production/year/ha	4250	2500	3250	1750	2750	2000	3500	2250
Average above ground biomass/culms/kg	9.0	5.5	11.15	8.2	9.0	6.0	8.5	7.0
Total accumulation of above ground biomass/ha/kg	38 250	13 750	36 230	14 350	24 750	12 000	29 750	15 750

* Values are means of three replicates.

Table 3.
Land equivalent ratio of agrisilvicultural models

Model	Pure agricultural crops yield (kg/ha)	Pure bamboo yield (kg/ha)	Intercropping		LER
			Agricultural crop yield (kg/ha)	Bamboo yield (kg/ha)	
Bamboo/pigeonpea	700	38 250	600	13 750	1.2
Bamboo/soybean	1700	36 230	1400	14 350	1.2
Bamboo/turmeric	6050	24 750	4300	12 000	1.1
Bamboo/ginger	1000	29 750	650	15 750	1.1

The average annual recruitment of bamboo culms is shown in Table 2. The number of culms produced was less than in pure bamboo stands. This may be mainly due to competition with the root systems of agricultural crops [13, 14]. Also, the unit area above ground biomass accumulation was found to be lower in intercropped bamboo stands.

The LER was 1.2 in the bamboo/pigeonpea and bamboo/soybean models, but 1.1 in the bamboo/turmeric and bamboo/ginger models. This means that the productivity of one hectare under intercropping is equivalent to that of 1.2 ha or 1.1 ha under monoculture (Table 3).

The results of the study revealed that pigeonpea or soybean are most suitable for intercropping of bamboo plantations, and turmeric and ginger are a good second choice.

Acknowledgement

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10 August 1999

Dear Dr Shanmughavel

Intercropping trials in bamboo plantations: an agroforestry study/
P. Shanmughavel and K. Francis

Your summary has now been reviewed by the D1 sub-plenary session review committee and I am pleased to inform you that it has been accepted for presentation as a poster, subject to revision according to the reviewers comments (overleaf). This means that a revised summary should be produced and submitted to me at the address given above by **31 October 1999** (see also the instructions given in the enclosed 'Model Summary for Congress Proceedings'). Because the reviewing process has taken longer than anticipated, we are able to extend the poster deadline if this is necessary in individual cases. Therefore, if you know that it will be difficult for you to submit your revised summary by 31 October, **please contact me immediately** to arrange a new deadline. If possible though, we prefer to remain with the original deadline of 31 October. The final version of your poster summary will be published in the Congress Proceedings. Details of the format that your summary should take are enclosed, as are information and advice on preparing your poster. The Best Poster Award is a new award to be presented at the XXI IUFRO World Congress in Malaysia 2000 and information on this is also enclosed.

Please confirm immediately whether or not you will be producing a poster. If you have any further enquiries, please contact me.

Yours sincerely

Michelle Jones

pp Dr Fergus L Sinclair
Organiser, sub-plenary session D1
Coordinator, IUFRO research group 1.15.00

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relationship between WUE and total biomass production indicated that even if WUE *per se* was less for all the trees, the available water was used economically for growth processes associated with the production of biomass.

The biomass production potential of tree species, indeed, depends on the ability to maintain higher photosynthetic rates. The data indicated that higher photosynthetic rates from May to August in *M. alba*, *G. optiva* and *B. variegata* resulted in higher total biomass production (t ha $^{-1}$) in these tree species.

Coppicing and pollarding significantly affected foliage as well as branchwood biomass production in all four species, with a maximum total biomass (12 t ha $^{-1}$) in *M. alba* followed by *G. optiva* (8 t ha $^{-1}$) pollarded at 2.0 m. Pollarding at 2.0 m cutting height is recommended as the best canopy management practice for producing higher total biomass in *M. alba* and *G. optiva* under rainfed conditions. The lower total biomass in *C. australis* is probably the result of inability of this tree species to withstand coppicing and pollarding over successive years.

Evaluating N-fixing Living Stakes for Organic Tomato (Lycopersicon esculentum) Production in Costa Rica

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Keywords: Biomass, Diseases, *Erythrina poeppigiana*, *Gliricidia sepium*, Nutrient concentration, Yield

Conventional tomato production on hillside farms in Costa Rica is costly to farmers and to human and ecosystem health. This cost could be reduced with the incorporation of soil improving leguminous shrubs into tomato farms and the concomitant reduction in use of agrochemicals, the main cost factor. Additionally, the output of tomato with an organic label is likely to appeal to health conscious consumers. A study was initiated in 1998 to evaluate two common N-fixing tree species as living stakes for tomato produced without applications of mineral fertilisers and insecticides, in an alley-crop arrangement of shrub and crop components. *Erythrina poeppigiana* seemed to influence a more favourable environment for higher foliar biomass and fruit yield in tomato than *Gliricidia sepium*. Tomato diseases which attacked in tandem were differentially favoured by the leguminous species. Growing tomato plants in *Gliricidia* plots had higher mortality from infection with *Pseudomonas solanacaerum* than in *Erythrina* plots. Fruiting tomato plants suffered higher fruit loss and plant mortality rates from infection with *Phytophthora infestans* in *Erythrina* plots than in *Gliricidia* plots. Support age and by implication the shading effect influenced the severity of *Phytophthora* infection. Tomato staked to eight-year-old *Erythrina*, compared to two-year-old stakes, were more affected by this disease. The mitigation of the favourable microclimatic conditions for *Phytophthora* and the reduction of competition for light is considered to be the most efficient approach, in order to optimise the crop production in an organic management system. Thus, a study was initiated in 1999 to evaluate the shoot pruning management of the leguminous living stakes with the specific aim to re-evaluate the variables mentioned above and to quantify the concomitant below-ground effects of shoot pruning of the two woody species. This study is currently supported by the International Foundation for Science. The biophysical interaction of two common leguminous species for organic tomato production in an agroforestry arrangement in the humid tropics is discussed.

Intercropping Trials in Bamboo Plantations

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Keywords: Bamboo plantations, *Bambusa bambos*, Intercropping, Pigeon pea, Growth, Yield, Land equivalent ratio (LER), Economics, Litter production, Nutrient return

Agroforestry is the practice of agriculture and forestry on the same piece of land. Bamboo (*Bambusa bambos*) is a household species and is the best friend of the farmers. The present crisis in sustained availability of bamboo can be resolved only by raising elaborate bamboo plantations. In India normally bamboo plantations are grown at a spacing of 6 x 6 m to meet the increasing demand for bamboo products. Research has increased rapidly in recent years to cultivate agricultural crops in the interspaces of bamboo plantations. This paper presents the results of intercropping trials with pigeon pea (*Cajanus cajan)* in bamboo plantations. The sampling area (4 ha) was a five-year-old plantation of pure bamboo. Throughout

this area, bamboo culms in their fourth and fifth years were harvested. Pruning was done of the remaining culms. One ha of this plantation was kept as a control. In the other three ha, bamboo was intercropped with pigeon pea (ICPL-88034) with 1:1 rows. In another trial sole pigeon pea was cultivated. The density of pigeon pea was 278 plants ha^{-1} and the grain yield obtained was 600 kg ha^{-1} (intercropped stand) and 700 kg ha^{-1} (pure stand). For bamboo, an average of 11 culms were produced in the intercropped stand compared with 19 culms in pure stands. The profitability of pure bamboo stands would be in the order of Rs. 24,900 (US $600), whereas the profitability of the intercropped bamboo stand would be in the order of Rs. 21,800 (US $510), which is slightly lower due to underground competition for nutrients and water in the intercropped stand. The profit obtained from the intercropped agricultural crop is Rs. 7,900 (US $190), whereas the net income from the pure pigeon pea crop is Rs. 13,000 (US $300).

The land equivalent ratio (LER) of bamboo producing culms (dry weight) with a pigeon pea intercrop showed:

Sole pigeon pea	Sole bamboo	Intercropping
0.7 t ha^{-1}	2.2 t ha^{-1}	0.6 t ha^{-1} grain + 0.9 t ha^{-1} culms

The land equivalent ratio of the system =

$$\frac{0.6}{0.7} + \frac{0.9}{2.2} = 1.2$$

This means that the productivity of 1 ha under intercropping is equivalent to that of 1.2 ha under the sole system. The bamboo plantations intercropped with pigeon pea produced a higher quantity of litter than pure bamboo stands. Litter fall followed a bimodal pattern with a principal peak in the winter and another in the late summer. Of the total annual litter production, leaf litter accounted for 58% and twig litter 42%. The annual litter production was 13.5 t ha^{-1} in the pure bamboo stand and 15.7 t ha^{-1} in the intercropped stand. With regard to nutrients, the highest concentration of N, P, Ca and Mg was in leaf litter. In twig litter, the maximum concentration of K was observed. On an annual basis 89, 6, 78, 42 and 49 kg ha^{-1} (pure bamboo stand) and 113, 9, 106, 52 and 60 kg ha^{-1} (intercropped stand) of N, P, K, Ca and Mg respectively was returned through leaf litter. The results from these studies can be used as a guideline for improvement of productivity in agroforestry models.

Economic Evaluation of Tea Based Agroforestry

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Keywords: Economic evaluation; Tea-ba
agroforestry; Linear programming; Returns-o
variable-cost; Employment generation

The present paper analyses the economics of t based agroforestry systems in the tea-grow pockets of Kangra and Mandi districts of Himac Pradesh (India). Himachal tea, commerci famous as *Kangra Tea*, is known for its str flavour and is often in demand for blending w Assam tea. The study was based on sur information obtained from 34 randomly selec agroforesters, spread over 12 villages in Palampur tea-growing region of the state.

Tea productivity of the area is substantially lo than that of other tea-growing areas in the coun The reasons for this are the geographically dist and infrastructurally underdeveloped area, dist markets, lack of trained labour and le restrictions on changing the land use pattern of tea gardens. Forest tree harvesting rules a contribute towards this, as at times harmful sh trees like *Pinus roxburghii* cannot be eas removed from the gardens. The surveyed farm on average, had a large number of trees (226) in gardens, pasture lands (189) and on the bunds agricultural holdings (30).

The linear programming technique was used formal analysis of the data. The exist agroforestry system on the sample farms v compared with two variants, one involving the allocation of existing resources under exist technology (Plan-I), and the second incorporat the use of technology recommended by the lo agricultural extension institutions (Plan-II). T systems were analysed in terms of their differ components (real activities) like forest trees, gardens, pasture lands, livestock and agricultu crops. The model thus consisted of 39 r activities and 34 constraints. The econon advantage of a system was measured in terms the net returns-over-variable-cost.

Under the existing management pattern, t average sample farm generated US$ 4232.02 p annum, of which the contribution of tea was nea 86%. Tea was followed by forest trees, which ha contribution of about 5%. Under Plan-I, there w a significant change in the suggested physi

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BAMBOO FOR AGRO-FORESTRY IN INDIA

by

P. SHANMUGHAVEL AND R..S.PEDDAPPAIAH *

Summary

This study mainly deals with the intercropping of agricultural crops in the established bamboo plantation. The growth, yield and interactions between the agroforestry systems are discussed. Some of the known combinations of agricultural crops with bamboo in India are presented. In all the agri-silviculture model, on an average of three replicates, the per plant yield of pure agricultural crops was found higher, when compared with intercropped stand. The production of new culms/ clump in the intercropped bamboo stand found minimum as compared with pure bamboo stand. The reasons are also discussed.

Introduction

Agroforestry is a collective name for all land use systems and practices, where woody perennials are deliberately grown on the same land management unit as agricultural crops or animals in some form of spatial arrangement or temporal sequence. Although considerable research has been undertaken on industrial plantations, community wood lots, alley farming etc., the information on the economics of farm forestry, especially the small plantations that are established by the individual farmers for the production of poles, fuel and fodder are very much limited . The products meet the farmers own needs and the surplus is sold in the market. The trees are primarily grown by the farmers to meet the requirement of small timber as well as for soil conservation and improvement . Bamboo is basically a household species and is the best friend of the farmers. It can be grown around houses, wells, compounds, on farmlands and other available places in the holdings. It is grown as homestead plantations because every part of it finds one use or another by the farmers. It is proven that bamboo can also be used as an ideal species for agroforestry system. The growth performance of red gram, soybean and turmeric, the economic returns, nutrient cycling by growing these species as intercrops in bamboo plantations are discussed.

Materials and Method

Study Area

The study area is located at Kallipatty, Tamil Nadu State, India, between 110 28' and 120 latitude and 76° 59' and 77° 47' longitude . The altitude is 540 masl. This area has red soils with pH between 7.4 and 7.8 and soil nitrogen , phosphorus and potassium are 3800, 360 and 3600 kg/ha respectively . The mean temperature is 32° C. Mean rainfall is 600 mm.

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Bamboo cultivation

Seeds produced from bamboo is scanty, hence plantation can be raised using seedlings obtained from tissue culture method. Seedlings were planted in pits of size 45 x 45 x 45 cm at an espacement of 6m x 6m (250 seedlings/ha-1). The upper halves of the pits were filled with a mixture of red earth, Farm Yard Manure (FYM) and 25g of 15:15:15 NPK fertilizer per plant. Brushwood fences were made in each seedling to protect them from rodents, grazing and browsing animals. Seedlings were adequately irrigated at 15 day intervals.

An average culm emergence of two per clump was observed one year after planting. The average annual recruitment increased in the subsequent years and numbered at 4-13 per clump. The culms that emerged in the first year were short and thin at breast height. Culms produced in the subsequent years were taller and bigger (Shanmughavel 1995). Recruitment of new culms goes on until it flowers (30-35 years depending on species). Raising bamboo plantation is thus a long term solution to farmers.

Inter cropping with Pigeon pea

Inter cropping of Pigeon pea in the established bamboo plantation was tried. Pigeon pea is a hardy pulse of tropical grassland and arid regions. It accounts for about 4% of the total pulse production in the world. The crop usually prefers a fairly moist climate during the period of its vegetative development . The crop may be grown in all kinds of soils, but it prefers a light and moist soil in which the roots can develop freely. ICPL -88034 -an extra short duration pigeon pea (10 months duration) was sown in bamboo plantations 1:1 rows at 3mx 3m spacing (density 250 plants / ha) and 1:2 rows at 2mx2m spacing (density 500 plants/ha). The growth and economic returns of agricultural crop was carried out after the harvest.

Inter cropping with Soybean

Inter cropping of soybean in the established bamboo plantation was tried. Soybean (Glycine max) is the most important legume crop in the world. It is grown under varying climatic conditions either as pure crop or as inter crop . The best results are obtained in fertile loam and sandy loam soils. M.A.C.S. 58 variety of soybean (6months duration) was sown in bamboo plantations 1:1 rows at 3m x 3m spacing (1111 plants per ha) during June. With inter cropping, only 35 percent of plants were established . The study on growth and economic returns of agricultural crop was carried out after the harvest.

Intercropping with Turmeric

Inter cropping of turmeric in the established bamboo plantations was tried. Turmeric is obtained from the under ground rhizomes of the plant. It belongs to the zinger family, Zingiberaceae. The crop requires a warm and moist climate. Well-drained fertile sandy and clayey medium black red or alluvial loam rich in humus and uniform in texture are highly suited for its cultivation. Therefore, there is a great need to identify suitable agricultural and horticultural crops, which can grow well with tree plantations with limited solar energy available.

Experimental design

The experiment is installed in a randomized complete block design with 4 replicates. The dimensions of the individual plots are 8m x 4m. Of the four replications, one block was kept as control whereas in the remaining three blocks, approximately 200 turmeric rhizomes were planted. For sowing, both round and finger-like rhizomes were cut into 1+ to 2 inches long pieces , each having at least one sound bud. The rhizomes were planted three inches deep and 0.5 feet a part in either direction. The crop was sown in the month of April (first week). A pure turmeric (app 220 plants) was also planted in the individual plot of 8m x 4m and kept as control . Harvesting was done at the end of January.

Comparisons between different agroforestry systems require calculations of yield on a per hectare basis. When calculating either a bamboo or turmeric yield, if 6 metres of bamboo and 4 metres of turmeric are harvested, then the approximate harvest area is 24m2. Conversion to a per hectare yield require multiplying the yield from six metres by 10000/24.

The land equivalent ratio is a convenient method to compare the biological productivty of these two arrangements by combining the two types of yield . It is defined as the land area in the sole system that would be required to produce the same yields as one hectare of inter cropping . It is calculated as follows.

$$LER = C_I / C_S + T_I / T_S$$

Here C_I and T_I are crop and tree yields under inter cropping and C_S and T_S are yields in the sole system (Rao and Coe 1992).

Results and Discussion

Yield and returns from Pigeon pea

Information on the productivity of agricultural crops grown under tree plantations in India is very limited and there is a high demand for the products of both agriculture and forestry. Since the density of pigeon pea was 500 plants / ha at 2m x 2m spacing and 250 plants / ha at 3m x 3m spacing, it was found that 600 kg and 700 kg of grain yield was obtained from one hectare respectively . Details on the expenditure for growing and harvesting etc., and income obtained are given in Table 1. The net income from pigeon pea inter planted with Bamboo amounted to Rs.7,900 /- (2m spacing) and Rs.13330 /- (3m spacing) at one year of age. Subsequent harvesting can be done after six months so that some revenue can also be obtained.

Yield and returns from Soyabean

The density of soybean sowed was 1,111 plants / ha , but only 35 percent of the plants were established in inter cropping . It was found that 1,400 kg/ha of grain yield was obtained in this study. Details on the expenditure for growing and harvesting etc and income obtained are presented in Table 2. It can be noted that the net income from soybean inter planted with bamboo amounted to Rs.8,300 /- after the harvest . From the

results, it can be concluded that soybean can be planted in the initial stages of the bamboo plantations.

Table. 1 Economic returns of pigeon pea in Agroforestry

DETAILS	SITE -I Spacing(2m x 2m) (Density 500 plants / ha)	SITE-II Spacing(3m x 3m) (Density 250 plants / ha)
EXPENDITURE:		
1. Preparation of land , pitting soil mixture , planting soil working , Casually replacement etc ., (up to 24 months)	Rs4,000	Rs. 2,000
2. Harvesting , processing and stocking	Rs.2,000	Rs.1,000
3. Other maintenance	Rs. 500	Rs. 500
4. total expenditure	Rs.6,500	Rs.3,500
INCOME:		
1.Grain yield (in kg)	600	700
2. Cost (Rs.24 / kg)	Rs.14,400	Rs.16,800
3. Total Income	Rs.14,400	Rs.16,800
4. Total Expenditure	Rs. 6,500	Rs. 3,500
5. Net Income / Rs /ha /yr	Rs. 7,900	Rs.13,300

Yield and returns from Turmeric

In this study, the inter cropped turmeric was harvested after ten months of planting. On an average of three replicates, the per plant turmeric yield was 0.160 gram (Table 1). While converting to a hectare basis, the productivity was 13,344 kg /ha. However, higher productivity of 19,182 kg/ha was found in the sole turmeric. Similar higher productivity in the sole plantation crops have also been reported in other studies (Seshadri 1985, Shanmughavel and Francis in 1998, 1999 Balaji 1991).

As in the agricultural crops, the culm recruitment of sole bamboo plantation was found to be high. The average number of newly produced culms per clump of inter cropped bamboo is was only 8 . However, 11 culms / clump were produced in the sole

bamboo plantation (Table -2). The lower production of culms may be due to the below ground competition for nutrients, water etc. (Bowen, 1984). Ultimately, unit area biomass accumulation was found to be lower in the inter cropped bamboo (12t/ha) compared with sole bamboo (24.7t/ha) plantation.

Table. 2 Economic Returns of Soybean in Agroforestry System

Details	Soybean in Agroforestry (in rupees)
Expenditure	
1. Preparation of land, pitting soil mixture, plantation , soil working perusal replacement etc. , (up to 10 months)	3,000
2. Harvesting , processing and stocking	1,100
3. Other maintenance	200
4. Total expenditure	4,300
Income	
1. Grain yield (in kg)	1,400
2. Cost (Rs.9%)	12,600
3. Total income	12,600
4. Total expenditure	4,300
5. Net income Rs/ha/yr.	8,300

Production Of Culms

In agrisilviculture, a set of fifteen clumps were randomly selected and marked with paints for the assessment of monthly production of culms. Every month, the number of newly sprouted culms and their survival were recorded . The observation continued for a full one year.

Underground root competition for moisture , nutrients and space is relatively more important in agro forestry systems than above ground crown competition. The productivity of bamboo is assessed by the number of new culms produced annually. At a given site, the production of new culms mostly depended on the degree of congestion, clump age, rainfall of the previous year and the nature of competition by the inter cropped agricultural crops, etc. The monthly productivity of culms of bamboos in a agrisilviculture model is presented in Table 3. It can be seen that on an annual basis, maximum production

of culms took place during September - November which was monsoon season analogous to the results of pure bamboo stands (Table 4) (Shanmughavel 1995). The number of culms produced were considerably reduced in comparison with pure bamboo stands. In the agrisilviculture model, an average of 9.9 culms of bamboos were produced , but in pure bamboo stands, an average of 17 culms were reported . This may be due to the competition with the deeper root system of pigeon pea.

It sends its roots deeper than 50 cm . It is argued that agricultural crops absorb nutrients from the soil usually from the top layer of 30 cm soil depth and to some extent up to 50 cm soil depth . A higher concentration of fine tree roots in the soil layer up to 50 cm suggests that trees also obtain most of the nutrient requirement from the soil layer up to 50 cm . The low concentration of fine roots below 50 cm soil depth suggests that the nutrient absorption from deeper soil layer may be small. The main function of the roots reaching greater depth appears to be water uptake, particularly during periods of water stress (Bowen 1984). This may be the reason for the minimum production of bamboo culms in the agrisilviculture model . However, their survival rate was further reduced drastically due to white ants and other physiological causes.

Land and Equivalent Ratio (LER)

The land equivalent ratio of bamboo producing culms (dry weight) with turmeric inter crop are shown as follows:-

Sole Turmeric	Sole bamboo	Inter cropping
19.1t/ha	24.7	13.3t/ha turmeric 12.0t/ha culms

- The land equivalent ratio of the system = 13.3/19.1+ 12.0/24.7 = 1.2

This means that the productivity of one hectare of bamboo under intercropping is equivalent to that of 1.2 ha under the sole system .

The results of the study revealed that turmeric can be recommended for the inter cropping with bamboo plantation for the benefit of farmers.

Litter Production And Nutrient Return In Agroforestry System

Litter production

The total annual litter production (t/ha) was lower in pure plantation in comparison with inter cropped stands. In the pure stands, it was 13.5 t/ ha, while in the stands inter cropped with pigeon pea, it was 15.7 t /ha (Table 5) The difference in total litter production in the pure and inter cropped stands was not significant. Singh et al., (1989) and Mohinson et al (1996) found maximum litter production in inter cropped poplar trees than their pure stands . The bamboo responds very well to different cultural and agronomical practices like hoeing, weeding, irrigation and use of fertilizers (Shanmughavel and Francis 1995). Therefore, higher litter productivity in the inter

Table 3: Monthly Production of Clums/Clumps in Agroforestry System

Month	1		2		3		4		5		6		7		8		9		10	
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S
January	2	..	3	..	3	1	..	..	2	..	3	1	4	..	3	1	4	1	3	1
February	3	2	2	2	3	1	3	..	2	..	3	..	3	1	2	..	3	1	2	..
March	4	..	3	..	4	1	3	1	3	1	3	1	4	1	3	1	4	1	3	..
April	3	..	4	1	2	..	3	..	4	..	3	1	4	..	2	..	4	1	3	..
May	3	..	4	..	3	..	2	..	4	1	3	1	3	..	..	..	2	1	2	..
June	4	1	3	1	2	1	4	1	3	1	2	..	2	1	4	..	3	1	2	1
July	3	..	2	..	1	..	4	1	3	0	2	1	4	1	3	1	4	0	3	..
August	4	1	4	2	5	2	3	1	6	3	4	..	4	2	4	1	5	2	4	2
September	4	3	3	1	2	..	4	2	4	2	3	2	5	3	5	2	6	4	3	..
October	4	2	4	2	2	..	4	2	4	3	4	1	4	2	3	1	3	2	4	3
November	2	..	2	1	2	1	4	..	2	1	3	1	3	..	4	1	3	1	2	..
December	1	..	2	..	3	1	3	1	2	..	4	2	3	..	3	1	4	..	1	..
Total		8		9		8		9		12		11		11		9		15		7

Table 4: Monthly Recruitment of Clums/Clumps

Month	Sample Clump Number																													
	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S
January	3	-	4	-	4	1	1	1	2	-	3	-	4	-	4	1	3	1	3	1	4	1	3	-	4	1	1	-	1	-
February	4	1	4	-	2	-	2	-	3	1	4	-	3	1	3	1	4	1	4	1	4	-	4	1	3	-	2	1	2	-
March	3	1	3	1	3	1	3	-	4	1	3	-	4	2	5	1	2	-	3	1	3	-	5	2	4	1	2	1	3	-
April	2	-	2	-	3	-	2	1	5	1	2	-	3	-	4	-	3	-	4	-	-	-	6	1	5	3	-	-	4	-
May	2	-	2	-	4	-	4	1	3	-	3	-	4	-	3	-	4	1	3	-	-	-	3	-	-	-	-	-	-	-
June	3	-	4	2	4	2	5	2	2	-	4	2	3	2	2	1	5	2	4	1	3	1	4	1	3	-	2	2	3	-
July	5	-	5	2	6	3	3	3	5	3	5	3	4	2	4	3	8	4	5	3	4	1	5	3	7	3	5	4	5	3
August	4	1	5	2	7	3	5	2	8	3	9	4	5	2	5	3	9	3	9	2	5	2	8	3	5	3	6	3	4	3
September	5	4	6	3	8	2	5	4	7	4	5	3	4	1	5	3	3	1	7	3	5	3	8	4	5	4	4	3	5	4
October	6	3	4	1	4	2	3	1	3	-	4	1	5	4	3	2	4	2	4	1	5	4	6	3	3	2	2	1	4	3
November	6	3	3	1	3	1	3	-	4	1	3	1	4	2	5	2	3	1	3	1	4	2	4	1	4	2	3	1	3	4
December	5	1	4	2	3	1	2	2	3	1	3	1	3	2	5	2	2	1	6	2	3	1	3	-	3	1	4	2	4	2
Total		14		14		17		17		15		17		18		19		17		16		15		19		20		18		19

Fifteen clumps were randomly selected from the sixth year plantation for the assessment of monthly - recruitment of clums and their survival were recorded. It revealed the maximum recruitment of the culms took place during September - November, which was the monsoon season. An average of 17 culms were produced from one Culm, during the year 1993.

C - Number of newly sprouted culm
S - Survival

cropped stands in the present study was expected due to intensive cultural operations given to Pigeon pea, which have ultimately helped the bamboo in producing more number of twigs and leaves and thus increased litter production.

Table. 5 Litter Production in Agroforestry System I (kg ha^{-1})

Month	Litter components					
	Leaves		Twigs		Total	
	P.S.	A.F	P.S.	A.F.	P.S.	A.F.
Jan	720±4	850±5.5	510±7.5	575±9.5	1230	1425
Feb	610±7.5	730±4.5	480±11.5	510±10	1090	1240
Mar	560±8	630±11	490+5	540+7	1050	1170
Apr	570±7.9	640±9	430±11	450±12	1000	1090
May	840±11	980±10	580±5	590±11	1420	1570
Jun	850±9.5	910±11	530±10	560±2.5	1380	1470
Jul	510±7	620±7	410±7	470±7.5	920	1090
Aug	540±2.5	690±10	470±5	490±8	1010	1180
Sep	625±5	640±9	460±7	610±11	1085	1250
Oct	560±9	610±5	440±5	590±5	1000	1200
Nov	690±10	950±4	550±5	580±0	1240	1530
Dec	940±5	990±7.5	510±0	540±7.5	1450	1530
Total	8015	9240	5860	6505	13875	15745

P.S. -Pure stand ; A.F - Agroforestry.

Nutrient Return

The concentration of N, P, K, Ca and Mg in the litter was found to be higher in the inter cropped than that of pure stands (Table 6) . The highest concentration of N, P, Ca and Mg was in the leaf litter , while in the twig litter, maximum concentration of K was observed. Similar results were observed by O' Conell and Manage 1982, Gill *et al.* 1987 and Mohsin *et al.* 1996. On an annual basis, 89, 6, 78, 42 and 49 kg /ha (pure bamboo stand) and 113, 9, 106, 52 and 60 kg /ha (Agroforestry system) of N ,P, K , Ca and Mg respectively were returned through litter fall. Maximum (42%) amount of all the nutrients

were returned through leaf-litter and lowest through twig litter (Tables 7). The type of vegetation grown under the tree also reflected soil property (Jacques *et al*. 1975, Seth *et al.* 1963). Nye and Greenland (1964) and Hazar and Tripathi (1986) have reported enrichment of the soil nutrients under the tree canopy. Therefore, the nutrients returned were found to be higher in the soil of the inter cropped bamboo stand.

Table. 6 Nutrient Concentration in Litter Components (mg / g)

Nutrients	Pure stand		Agroforestry	
	Leaves	Twigs	Leaves	Twigs
N	7.8±0.05	4.5± 0.04	3.3± 0.07	5.5± 0.02
P	0.5±0.03	0.4± 0.04	0.6± 0.04	0.5± 0.04
K	5.0±0.04	6.5± 0.04	6.5± 0.08	7.0± 0.07
Ca	3.1±0.03	2.9± 0.04	3.5± 0.03	3.0± 0.04
Mg	3.7±0.04	3.2± 0.05	4.0± 0.04	3.5± 0.05

Table. 7 Nutrient Return Through Litter Fall (kg ha-1)

Nutrients	Pure stand			Agroforestry		
	Leav es	Twigs	Total	Leaves	Twigs	Total
N	63	26	89	77	36	113
P	4	2	6	6	3	9
K	40	38	78	60	4 6	106
C a	25	17	42	32	20	52
Mg	3 0	19	49	3 7	23	60
Total	162	102	264	212	128	340

Table. 8 Yield of Turmeric in a pure and inter cropped plantation

S.No		Inter cropped turmeric	Pure Turmeric
1.	Total number of Turmeric planted/ unit area	200	220
2.	Average yield (kg / plant)	0.160	0.210
3.	Productivity unit area (kg)	32	46
4.	Yield per hectare (kg ha-1)	13.344	19.182

Table. 9 Production of culms and the accumulation of above ground biomass in a pure and inter cropped Bamboo stand

S.No.		Inter cropped stand	Pure stand
1.	Average production of culms / clump/ year	8	11
2.	Total number of clumps per ha	250	250
3.	Culm production in hectare	2000	2750
4.	Average above ground biomass / culm kg	6	9
5.	Total above ground biomass (kg / ha)	12,000	24,750

Economics

Farmers can get substantial income from the agricultural crops every season. In addition, cultivation of bamboo can provide a cost effective return within the short term (3 years). Balaji (1991) reported that the scope for bamboo in agroforestry is very wide because of the uncertain weather conditions and increasing cost of labour involved in agriculture these days. Even small or marginal farmer can get substantial income from Rs.800 - Rs.1,000/- once in three years from just one clump of bamboo planted with agricultural crops.

Agroforestry systems will not only help the farmer in getting better returns from his land but also plant trees in the rural areas that can check wind erosion, conserve the precious top soil and water and ameliorate the immediate environment in the rural areas.

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CULMS PRODUCTION OF BAMBOOS IN AN AGROFORESTRY SYSTEM

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Abstract

The present study was carried out to find out the extent of interactions in underground root system in the agroforestry model. Pigeon pea (*Cajanus cajan*) intercropped in the established bamboo plantations at the espacement of 3 x 3 m. On an annual basis an average of 9.9 culms per clump in bamboo was produced. Culm production was monsoon dependent. The reasons for minimum production of culms is discussed.

Introduction

In the quest of increasing productivity the multi-tier system "agroforesty" has assumed wider recognition. Agroforestry aims to maximise production of biomass of trees and agricultural crops. The combination of agricultural crops with trees vary between regions (Dwivedi 1992). Bamboos are giant, woody, tree like grasses with a long history as an exceptionally versatile and widely used resource. Compared with the vast resources of bamboo found in South and South-east Asia, at the beginning of this century we are left with the current situation of acute scarcity. The present crisis in sustained availability can be ensured only by raising elaborate bamboo plantations (Shanmughaval 1995). In India, bamboo plantation has been raised extensively at the espacement of 6 x 6 m to meet the increasing demand of the bamboo products. Research has increased rapidly in recent years to cultivate agricultural crops between the espacement in bamboo plantations. In the present study intercropping of pigeon pea in established bamboo plantation was tested (Agrisilviculture model). Interactions in agroforestry system can be classified into above ground and below ground parameters. The above ground interactions investigated in this zone indicated varied results from species to species (Sharma 1992 & 1995 & Sharma & Unnikrishnan 1991) but a very little information is available on below ground interactions (Sharma & Gulati 1997). Therefore the main objective of this investigation was to assess the production of new culms in bamboos in agrisilviculture model on every month and their survival rate.

Material and Methods

Study area: The study area is located at Kallipatty, (11° 28' and 12° N latitude and 76° 59' and 77° 47' E longitude; altitude 540 MSL) Tamil Nadu State, India. This area has red soil with pH ranging between 7.4 and 7.8. Soil nitrogen, phosphorus and potassium were 3800, 360 and 3600 kg per hectare respectively. The mean temperature and rain fall is 31°C and 600 mm respectively.

Bamboo plantations: The seedlings of *Bambusa bambos* were planted with 6 x 6 m spacing in 3 ha with 250 seedlings per ha. Seedlings produced culms during the next year of transplantation. Since then culms were treated as one year old. On an average of 5 culms emerged during the first year and gradually increased in subsequent years. Culms emerging during the first year were short (1.4 m) in length and thinner (2.3 cm dbh). However, culms produced during the subsequent years were distinctly taller and thicker up to 6 years, after which both height and dbh began to decline.

'ntercropping (Pigeon pea) : Intercropping of pigeon pea (*Cajanus cajan*) in the established bamboo plantations was done. Pigeon pea is a hardy pulse of tropical grassland and arid regions, which accounts for about 4% of total pulse production in the world. The crop usually prefers a fairly moist climate during the vegetative phase. The crop may be grown in a wide variety of soils but a light and moist soil in which the roots can develop freely is optimum. ICPL - 880 34 - an extra duration pigeon pea (10 months duration) was sown in bamboo plantations, 1:1 rows at the espacement of 3 x 3 m.

Production of Culms

In the agrisilviculture a set of fifteen clumps were randomly selected and marked with paints for the assessment of monthly production of culms. Every month the number of newly sprouted culms and their survival were recorded. The observation continued for three years.

Results and Discussion

Underground root competition for moisture, nutrients and space is relatively more important in agroforestry systems than above ground crown competition. The productivity of bamboo assessed by the number of new culms produced annually. At a given site the production of new culms mostly depended on the degree of congestion, clump age, rainfall of the previous year and the nature of competition by the intercropped agricultural crops, etc. The monthly productivity of culms in bamboos in agrisilvicultural model is presented in Table-1. It revealed that on an annual basis maximum production of culms took place during September-November which was North-west monsoon season in Tamil Nadu analgous to the results of pure bamboo stands (Table-2, Shanmughgavel, 1995). Culm production was considerably low compared to pure bamboo stands Table-3). In agrisilviculture model an average of 11 culms were produced compared to 19 culms on pure bamboo stands. This may be due to the elaborate root system of pigeon pea which sends the roots deeper than 50 cm and competing for nutrients. Generally agricultural crops absorb nutrients from the soil usually from the top 30 cm of soil and to some extent up to 50 cm. A higher concentration of fine tree roots in the soil layer up to 50 cm suggests that trees also obtained most of the nutrient requirements from the soil layer up to 50 cm. The low concentration of fine roots below 50 cm soil depth suggests that the nutrient absortion from deeper soil layers may be small. The main function of the roots reaching greater depths appears to be water uptake, particularly during periods of water stress (Bowan 1984). This may be the reason for the minimum production of culms in bamboos in agrisilviculture model. However, their survival rate was further drastically reduced due to termites (white ants) and other physiological causes.

Table-1: Monthly production of culms in Bamboos in agroforestry

Month	Sample clump number																			
	1		2		3		4		5		6		7		8		9		10	
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S
January	2	..	3	..	3	1	..	..	2	..	3	1	4	..	3	1	4	1	3	1
February	3	1	2	1	3	1	3	..	2	..	3	..	3	1	2	..	3	1	2	..
March	4	..	3	..	4	1	3	1	3	1	3	1	4	1	3	1	4	1	3	..
April	3	..	4	1	2	..	3	..	4	..	3	1	4	..	2	..	4	1	3	..
May	3	..	4	..	3	..	2	..	4	1	3	1	3	..	..	..	2	1	2	..
June	4	1	3	1	2	1	4	1	3	1	2	..	2	1	4	..	3	1	2	1
July	3	..	2	..	1	..	4	1	3	0	2	1	4	1	3	1	4	0	3	..
August	4	1	4	2	5	2	3	1	6	3	4	..	4	2	4	1	5	2	4	1
September	4	3	3	1	2	..	4	2	4	2	3	2	5	3	5	2	6	4	3	..
October	4	2	4	2	2	..	4	2	4	2	4	1	4	2	3	1	3	2	4	3
November	2	..	2	1	2	1	4	..	2	1	3	1	3	..	4	1	3	1	2	..
December	1	..	2	..	3	1	3	1	2	..	4	2	3	..	3	1	4	..	1	..
Total culms	8		9		8		9		12		11		11		9		15		7	

C = Number of newly sprouted culms; S = Survival

Table-2: Monthly recruitment of culms/clump

Month	Sample clump number																											
	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	
	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S	C	S
January	3	-	4	-	4	1	1	1	2	-	3	1	4	-	4	1	3	1	3	1	4	1	3	-	4	1	1	-	1	1
February	4	1	4	-	2	-	2	-	3	1	4	1	3	1	3	1	4	1	4	1	4	-	4	1	3	-	2	1	2	1
March	3	1	3	1	3	1	3	-	4	1	3	-	4	2	5	1	2	-	3	1	3	-	5	2	4	1	3	1	3	1
April	2	-	2	-	3	-	2	1	6	1	2	-	3	-	4	-	3	-	4	-	-	-	6	1	5	2	-	-	4	1
May	2	-	2	-	4	1	4	1	3	-	3	-	4	-	3	-	4	1	3	-	-	-	3	-	-	-	-	-	-	-
June	3	-	4	2	4	2	6	2	2	-	4	2	3	2	2	1	5	2	4	1	3	1	4	1	3	1	4	2	3	1
July	5	-	5	2	6	3	8	3	6	3	6	3	4	2	4	3	8	4	6	3	4	1	6	3	7	3	5	1	6	3
August	4	1	5	2	7	3	6	2	8	3	9	4	6	2	6	3	9	3	9	2	5	2	8	3	5	3	6	3	4	2
September	8	4	6	3	8	2	6	4	7	4	6	3	4	1	6	3	3	1	7	3	6	3	8	4	6	4	4	3	6	4
October	6	3	4	1	4	2	3	1	3	-	4	1	6	4	3	2	4	2	4	1	6	4	6	3	3	2	2	1	4	3
November	6	3	3	1	3	1	3	-	4	1	3	1	4	2	6	2	3	1	3	1	4	2	4	1	4	2	3	1	3	1
December	6	1	4	2	3	1	2	2	3	1	3	1	3	2	5	2	2	1	6	2	3	1	3	-	3	1	4	2	4	2
Total culms	16		14		17		17		15		17		18		19		17		16		15		19		20		15		20	

Fifteen clumps were randomly selected from the sixth year plantation for the assessment of monthly - recruitment of culms and their survival were recorded. It revealed the maximum recruitment of the culms took place during September-November, which was the monsoon season. An average of 17 culms were produced from one clump, during the year 1993.

C- Number of newly sprouted culms
S- Survival

Table-3: Monthly production of culms in bamboo plantations

Stand	Year 1	Year 2	Year 3
Pure	17 ± 3	19 ± 4	21 ± 5.5
Agroforestry*	10 ± 1	11 ± 1.5	13 ± 2.5

* Average of 10 clumps

Economics

The details of simple economic analysis of cost and benefit of these plantations are presented in Table-4. On the whole in pure stands 15750 culms were produced of which 7000 culms per ha were mature and eligible for exploitation, whereas in agroforestry 2250 culms were obtained of which 1230 culms per ha were well matured and can be used. From the data obtained on financial aspect (Table-4) it could be seen that the profitability of pure bamboo stand would be in the order of Rs. 21,800 per ha per year (discounting analysis has to be done for reckoning with waiting period), whereas the profitability of bamboo intercropped with agricultural crop would be of the order of Rs. 24,900 per ha per year (Table-4). Besides this, an additional profit of Rs. 7900 from *cajanus cajan* crop can be obtained from intercroping whereas the net income from the sole pigeon pea is Rs. 13,300 per ha per year (Table-5).

Table-4: Cost benefit analysis for bamboo plantations*

		Pure stand in Rs.	Agroforestry in Rs.
1.	Total number of culms (all years)	15750	2250
2.	Matured culms (elgible for exploitation)	7000	1230
3.	Price of one culm (average)	30	30
4.	Total revenue per ha	210000	36900
5.	Expenditure for maintenance, etc.	101000	12000
6.	Profit	109000	24900
7.	Net profit per ha	21800	24900

*Discounting analysis has to be done for reckoning with the waiting period.

Table-5: Economic returns of Pigeon pea in agroforestry and pure crop

Details	Agroforestry (3 m x 3 m) Spacing (Density 500 plants/ha)	Pure (3 m x 3 m) Spacing (Density 500 plants/ha)
EXPENDITURE :		
1. Preparation of land, pitting soil mixture, planting, soil working, casual replacement, etc. (up to 24 months)	Rs. 4,000	Rs. 2,000
2. Harvesting, processing and stocking	Rs. 2,000	Rs. 1,000
3. Other maintenance	Rs. 500	Rs. 500
5. Total expenditure	Rs. 6,500	Rs. 3,500
INCOME :		
1. Grain yield (in kg)	600	700
2. Cost (Rs. 24/kg)	Rs. 14,400	Rs. 16,800
3. Total Income	Rs. 14,400	Rs. 16,800
4. Total Expenditure	Rs. 6,500	Rs. 3,500
5. Net Income/Rs./ha/yr.	Rs. 7,900	Rs. 13,300

Conclusion

The result from the present studies of agroforestry model can be used as a guideline for improvement of productivty in agroforesty model as well as for improvement of income distribution.

Acknowledgement

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LITTER PRODUCTION AND NUTRIENT RETURN IN AGROFORESTRY SYSTEM

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Abstract : A field study was conducted to investigate the litter production and nutrient return behaviour of Bamboo in an agroforestry system. The combined crop of bamboo plantation intercropped with Pigeon pea produced higher quantity of litter than pure bamboo stand alone. The litter fall for all ages of plant indicated bimodel pattern with a principal peak in the winter and another in the late summer. Of the total annual litter production, leaf-litter accounted for 58% and twig-litter 42%. The annual litter production was 13.5 t ha^{-1} in pure bamboo stand and 15.7 t ha^{-1} in the above agroforestry system. With regards to nutrients highest concentration of N, P, Ca and Mg was in leaf-litter. In twig litter maximum concentration of K was observed. On an annual basis, 89, 6, 78, 42 and 49 kg ha^{-1} (Pure bamboo stand) and 113, 9, 106, 52 and 60 kg ha^{-1} (Agroforestry system) of N, P, K, Ca and Mg respectively were returned through litter fall. Maximum amount of all the nutrients were returned through leaf-litter and lowest through twig litter.

INTRODUCTION

Agroforestry aims to maximise biomass production of trees together with agricultural crops. Recent researches favour cultivation of agricultural crops in the space between rows of bamboo plantations (Dwivedi, 1992). Bamboo is a fast growing arborescent grass. However, the litter if allowed to stay on its soil can replenish the lost nutrients. Bamboo is recommended as a companion species with several conventional and non-conventional crops in the agroforestry systems commonly used. However there is a dearth of information on the response of litter production in bamboo based agroforestry systems incorporating pigeon pea, affecting the nutrients recycling and soil fertility through tree and companion crops. Nair (1984) has indicated the potential benefit of growing tree in combination with annual and perennial crops so as to maintain and even enhance soil productivity. Therefore an investigation was conducted to assess the litter production and nutrient recycling in an Agroforestry system of a bamboo plantation.

MATERIALS AND METHODS

Study Area: The study covered an area of plantations of *Bambusa bambos* located at Kallipatty, Tamil Nadu lying in beween latitude 11.28 and 12°E and longitude 76.59 and 77.47°N at an altitude of 540 m above mean sea level. This area has red soil and its pH 7.4. The maximum soil nitrogen, phosphorus and potassium were 3800, 360 and 3600 kg ha respectively. The mean temperature is 31°C and the mean annual rainfall about 600 mm.

Plantation Details: The sampling area (2 hectare) is a plantation of pure bamboo stands (*Bambusa bambos*). Density was 1500 culms ha^{-1}. The mean culm height and DBH were 12.5 m and 3.0 m respectively. Of the two, one hectare was left without any intercrop and the other was intercropped with pigeon pea (*Cajanus cajan*), ICPL 88034 (10 months duration) pigeon pea.

Litter Determination and Nutrient analysis: The annual litter fall production of the bamboo in intercropping as well as in pure stands was recorded by collecting all leaves and twigs falling in litter traps on the soil surface. The litter samples were collected and pooled together to represent annual fall. A sample representative of each annual litter-fall from intercropping and pure stands was oven dried and subjected to further chemical analysis for nitrogen and phosphorus (Armstrong *et al.*, 1995) by Technicon Auto analyzer II (Gedko International Ltd.,

U.K) and for potassium (ISSAC and Johnson, 1975) by using an Atomic Absorption Spectrophotometer (Perkin Elmer 5000, USA).

RESULTS AND DISCUSSION

Litter Production : The total annual litter production (t ha^{-1} yr^{-1}) was lower in pure plantation in comparison to intercropped stands. In the pure stands it was 13.5 t ha^{-1}, while in the stands intercropped with Pigeon pea, it was 15.7 t ha^{-1} (Table-1). The difference in total litter production in the pure and intercropped stands was not significant. Singh *et al.* (1989) and Mohinson *et al.* (1996) found maximum litter production in intercropped Poplar trees than their pure stands. The bamboo responds very well to different cultural and agronomical practices like hoeing, weeding, irrigation and use of fertilizers (Shanmughavel and Francis, 1995). Therefore higher litter productivity in the intercropped stands in the present study was expected due to intensive cultural operations given to Pigeon pea, which have ultimately helped the bamboo in producing more number of twigs and leaves and thus increased litter production.

Nutrient Return: The concentration of N, P, K, Ca and Mg in the litter was found to be higher in the intercropped than that of pure stands (Table-2). The highest concentration of N, P, Ca and Mg was in leaf litter. In twig litter maximum concentration of K was observed. Similar results were observed by O'Connel and Manage (1982), Gill *et al.* (1987) and Mohsin *et al.* (1996). On an annual basis, 89.6, 78, 42 and 49 kg ha^{-1} (Pure bamboo stand) and 113, 9, 106, 52 and 60 kg ha^{-1} (Agroforestry system) of N, P, K, Ca and Mg was returned through litter-fall. Maximum (58%) amount of all the nutrients were returned through leaf-litter and lowest through twig-litter (42%) (Table-3). The type of vegetation grown under the tree also reflected soil property (Jacques *et al.*, 1975; Seth *et al.*, 1963). Nye and Greenland (1964) and Hazra and Tripathi (1986) have reported enrichment of the soil nutrients under the tree canopy. Therefore, the nutrients

Table-1: Litter Production in Agroforestry system (kg ha^{-1})

Month	Litter components					
	Leaves		Twigs		Total	
	P.S	A.F	P.S	A.F	P.S	A.F
Jan	720 ± 4	850 ± 5.5	510 ± 7.5	575 ± 9.5	1230	1425
Feb	610 ± 7.5	730 ± 4.5	480 ± 11.5	510 ± 10	1090	1240
Mar	560 ± 8	630 ± 11	490 ± 5	540 ± 7	1050	1170
Apr	570 ± 7.9	640 ± 9	430 ± 11	450 ± 12	1000	1090
May	840 ± 11	980 ± 10	580 ± 5	590 ± 11	1420	1570
Jun	850 ± 9.5	910 ± 11	530 ± 10	560 ± 2.5	1380	1470
Jul	510 ± 7	620 ± 7	410 ± 7	470 ± 7.5	920	1090
Aug	540 ± 2.5	690 ± 10	470 ± 5	490 ± 8	1010	1180
Sep	625 ± 5	640 ± 9	460 ± 7	610 ± 11	1085	1250
Oct	560 ± 9	610 ± 5	440 ± 5	590 ± 5	1000	1200
Nov	690 ± 10	950 ± 4	550 ± 5	580 ± 10	1240	1530
Dec	940 ± 5	990 ± 7.5	510 ± 0	540 ± 7.5	1450	1530
Total	8015	9240	5860	6505	13875	15745

P.S - Pure stand; A.F - Agroforestry

Table-2: Nutrient concentration in Litter components (mg g^{-1})

Nutrients	Pure stand		Agroforestry	
	Leaves	Twigs	Leaves	Twigs
N	7.8 ± 0.05	4.5 ± 0.04	8.3 ± 0.07	5.5 ± 0.02
P	0.5 ± 0.03	0.4 ± 0.04	0.6 ± 0.04	0.5 ± 0.04
K	5.0 ± 0.04	6.5 ± 0.04	6.5 ± 0.08	7.0 ± 0.07
Ca	3.1 ± 0.03	2.9 ± 0.04	3.5 ± 0.03	3.0 ± 0.04
Mg	3.7 ± 0.04	3.2 ± 0.05	4.0 ± 0.04	3.5 ± 0.05

Table-3: Nutrients return through Litter Fall (kg ha^{-1})

Nutrients	Pure stand			Agroforestry		
	Leaves	Twigs	Total	Leaves	Twigs	Total
N	63	26	89	77	36	113
P	4	2	6	6	3	9
K	40	38	78	60	46	106
Ca	25	17	42	32	20	52
Mg	30	19	49	37	23	60
Total	162	102	264	212	128	340

returned were found to be higher in the soil of the intercropped stand.

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GROWTH PERFORMANCE AND ECONOMIC RETURNS OF *LEUCAENA LEUCOCEPHALA* IN AGROFORESTRY

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Abstract

An attempt has been made to assess the growth performance and economic returns of *Leucaena leucocephala* in agroforestry systems. Two sites were selected in Coimbatore District of Tamil Nadu. Based on the results obtained, the farmers can also use its leaves as forage for their cattle. The plantation of *L. leucocephala* is profitable and also suitable for waste lands.

Introduction

Although considerable research has been undertaken on industrial plantations, community wood lots, alley farming, etc., information on the economics of farm forestry, especially the small plantations that are established by the individual farmers for the production of poles, fuel, fodder, are very much limited (Balaji, 1991; Sharma, 1992; Shanmughavel and Francis, 1998). Trees are primarily grown by the farmers to meet the requirements of small timber, fodder, as well as for soil conservation and soil improvement. In all the systems, multipurpose trees like *Leucaena leucocephala, Gliricidia maculata, Acacia nilotica, Azadirachta indica,* etc., are considered more useful.

L. leucocephala is a fast growing multipurpose tree species which grows best in neutral to alkaline soils where the annual rainfall ranges from 600-1700 mm. It has got considerable tolerance to salt, but grows poorly in acidic soils. The plant has deep tap root system, and is capable of absorbing large quantities of nitrogen (400 to 500 kg/ha/yr). It helps to enrich the soil with nitrogen and also to improve soil texture. Farmers grow *Leucaena* since it is a very good source of fuel-wood with high calorific value (4200 to 4600 Kcals/kg), as well as produces large quantities of forage which is highly palatable, digestive and nutritious. In the present article, results of the studies carried out on the growth performance of *L. leucocephala* and the economic returns by growing this species plantation in farm field are discussed.

Study site

Two sites were selected in Coimbatore District of Tamil Nadu, which lies inbetween 77°-0' and 77°-15' longitude and 10°-45' to 11°-0' latitude, for raising plantations under rain fed condition. The area receives an average annual rainfall of 600-800 mm of which the major portion is contributed by north-east monsoon and the average annual temperature is 26.4°C. The main agriculture crops are *Vigna radiata, Macrotyloma uniflorum, Vigna unguiculata, Sorghum bicolor,* etc. Site I has soils of sandy loam in texture with pH varying from 6.3 to 6.8. It has a hard pan of calcic horizon below a depth of 45 cm from the surface. Site II has soils of clay in texture with pH varying from 8.3 to 8.6. It has fragments of calcium deposits below a depth of 90 cm from the surface. The other characters of soils from both sites are given in Table-1.

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Table-1: Soil characteristics of two sites

Site Number	Texture	pH	EC	N(%)	P(%)	K(%)
I	Sandy loam	6.5	5.9	0.21	241.1	4136
II	Clay	8.3	0.24	0.05	123.1	2726

Materials and Methods

Plantations were raised by planting potted seedlings of *L. leucocephala* in 2 x 1 m espacement. Thus the density remained 5000 trees/ha. In both the sites, pits of size 1 cft were taken and refilled with potting mixture comprising of native soil and farmyard manure. At the end of 6th and 12th months, soil working, weeding and casualty replacements were carried out and during second year 80% survival was observed. Another soil working and weeding was carried out during 3rd year and 70% survival was recorded. Thus 3500 trees/ha were maintained till the 5th year. At the end of the 5th year, height and basal girth were recorded and representative trees were felled and different components such as wood, branch and leaves were separated and fresh weights recorded. Roots of the sample trees were also excavated for dry weight estimation. Samples were oven dried and dry matter production was estimated. Total biomass on unit area basis was worked out and is given in Table-2.

Table-2: Growth parameters and biomass production (tonnes/ha) of *L. leucocephala* in different sites (age: 5 years; density: 3500 trees/ha)

Site No.	Height (m)	Basal girth (cm)	Leaf (t/ha)	Twigs (t/ha)	Branch (t/ha)	Wood (t/ha)	Total (t/ha)	Root (t/ha)	Grand total (t/ha)
I	7.8	35.4	7.1	1.8	13.1	87.1	109.1	29.8	138.9
II	7.0	27.0	3.9	0.9	6.8	38.2	49.8	18.9	68.7

Results and Discussion

It is seen from Table-2 that, though there was not much difference in the height growth of trees between two sites, there was considerable difference in the girth. The basal girth of trees in site I was more than that of site II. As a result the biomass production was also considerable higher. The dry matter production of various components in site I was more than two times that in site II. However the percentage distribution of various components does not show much variations between site. For example the percentage of wood biomass ranges from 77 to 79% of the above ground biomass. Similarly the branch and leaf (leaf-twig) biomass constituted 12-14% and 8-10% respectively. The percentage of root biomass was 21% in site I and 28% in site II which indicates that the proportion of growth of root in site II was much more, when compared to site I. Since the water holding capacity is higher in clay than in sandy loam soil the quantity of roots formation is more and hence more biomass in site II. The green leaf production was 7.1 and 3.9 in site I and II respectively.

Market survey was conducted to work out the economics of raising *L. leucocephala* plantations for fuel-wood production. Details on the expenditure incurred in raising, maintaining and harvesting plantations were worked out. The economic returns were also worked out and the results obtained are given in Table-3.

The cost of raising the entire plantation and maintaining it until maturity was Rs. 12,500 at site I and Rs. 12,500 at site II. The expenditure incurred

Table-3: Economic returns from agroforestry (Farm Forestry). Age: 5 years

L. leucocephala	Density: 3500 trees/ha	
	Site I	Site II
Fuel-wood (stem wood)	87.1	38.2
Cost of fuel @ Rs. 1800/t	1,56,780	68,760
Fuel-branch @ Rs. 1400/t	13.1	6.8
Cost	18,340	9,520
Root @ Rs. 500/t	29.8	18.9
Cost	14,900	9,450
Total Cost	1,90,020	87,730

on harvesting and other processing was Rs. 16,200 at site I and Rs. 9,600 at site II. The total productivity obtained per unit area is 138.43 tonnes at side I and 58.47 tonnes at site II.

From the financial results obtained, it could be seen that a total income of Rs. 1,90,020 at site I and Rs. 87,730 at site II was obtained after 5 years (Table-4). The total expenditure incurred till

Table-4: Expenditure and income of *L. leucocephala* plantation in agroforestry systems during 5 years period

Expenditure :

L .leucocephala	Density: 3500 trees/ha	
	Site I	Site II
Preparation of land, pitting, soil mixture, planting, seedling cost, weeding, soil working, casualty replacement, etc.	12,500	12,500
Harvesting and processing, stacking	7,200	4,200
Loading, unloading and transportation, excavation of roots	@ Rs. 900/load with 10 t/load 9,000	@ Rs. 900/load, 6 load 5,400
Total tonnes	138.43 tonnes	58.47 tonnes
Total expenditure	28,700	22,100

Income:

	Site I	Site II
Total income	1,90,020	87,730
Total expenditure	28,700	22,100
Net income	1,61,320	65,630
Net income Rs./ha/yr	32,264	13,126

Table-5: Cost-benefit analysis for *L. leucocephala* in agroforestry systems

Site No.	Cost	Benefit	Present value under different discount rate					
			12%		14%		16%	
	(Rs.)	(Rs.)	Cost	Benefit	Cost	Benefit	Cost	Benefit
Site I	28,700	32,264	25,256	28,393	24,682	27.748	24,108	27,102
Site II	22,100	13,126	19,448	11,551	19,006	11,289	18,564	11,026
Total	50,800	45,390	44,704	39,944	43,688	39,037	42,672	38,128

Discount rates: 12% B/C ratio-0.89 14% B/C ratio-0.89 16% B/C ratio-0.89

1US$= Rs. 46.00

maturity and harvesting was Rs. 28,700 at site I and Rs. 22,100 at site II. The net income obtained was Rs. 1,61,320 at site I and Rs. 65,630 at site II. So, the profitability of *L. leucocephala* cultivation would be in the order of Rs. 32,264 at site I and Rs. 13,126 at site II (Discounting analysis has to be done for reckoning with the waiting period 5 years). Moreover the farmers can also use its leaves as forage for their cattle. So, the raising of *L. leucocephala* in the wastelands has been suggested from this study.

The details of simple economic analysis of cost-benefit is presented in Table-5. It is noticed that cost-benefit ratio (B/C) is 0.89 at 12, 14 and 16 per cent discount rate.

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Experimental Testing of Two Agri-Silvi-Cultural Models for Semi-Arid Regions

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K. Francis

ABSTRACT. Two models for the concurrent production of agricultural, horticultural and forest crops were attempted. The yield and economic returns from the models are discussed. Model A, a combination of *Moringa oleifera*, *Casuarina equisetifolia*, and maize, and Model B, comprised of *Moringa oleifera*, *Acacia aruriculiformis* and maize, were experimentally grown with suitable spacing of species and individual plants. In this study, the total net income was found to be higher in Model A than Model B. However, the cost-benefit ratio (B/C) in Model B exceeded 2:1, indicating very good financial results for this model as well. Both models provide food, fuel, fodder and small timber production in addition to employment to rural populations. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <http://www.HaworthPress.com>* *© 2003 by The Haworth Press, Inc. All rights reserved.]*

KEYWORDS. Agri-silvi-culture, *Moringa oleifera*, *Casuarina equisetifolia*, *Acacia aruriculiformis*, maize, yield, returns, cost-benefit ratio

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INTRODUCTION

Multiple land-use plans have been designed that include the potential for the production of both agricultural crops and forest crops, either simultaneously or alternately (FAO, 1978). The benefits of many agroforestry practices have been well illustrated by Raintree and Hoskins (1988), Singh et al. (1987), Shankaranarayan et al. (1987), ICFRE (1996a, 1996b), and Shanmughavel and K. Francis (1999a, 1999b). However, a study conducted by Reddy and Sudha (1988) revealed that a combination of agri-horticulture was most suitable for adoption by dry land farmers. Hence, a collaboration by the Institute of Forest Genetics and Tree Breeding and Bharathiar University, Coimbatore, India has attempted to assess two agri-silvi-cultural models employing different multipurpose tree species. The yield and economic returns from these models are presented in this paper.

MATERIALS AND METHODS

Study Site

The study site was situated in the Coimbatore district of Tamil Nadu, India, from 10°50′ to 11° N latitude and 77° to 77° 10′E longitude with a mean altitude of 350 meters above sea level. Climate is influenced by the southwest and northeast annual monsoons and average annual rainfall is 600 mm. The soil varies from sandy loam to sandy clay loam with pH ranging from 7.5 to 8.5. Soil nitrogen, phosphorus, potassium, calcium and magnesium were present in concentrations of 3400, 280, 3100, 1700 and 1900 kg/ha, respectively.

Development of Models

Model A: Moringa oleifera and Casuarina equisetifolia as Tree Components

M. oleifera seedlings raised in polybags were inoculated with biofertilizer (Azospirrillum) and planted with a spacing of 4 m between plants and 7 m between rows in pits of size 30 cm × 30 cm. In between each pair of *M. oleifera* plants, a *C. equisetifolia* seedling was planted in a pit of the same dimensions. The densities of *M. oleifera* and *C. equisetifolia* seedlings were each 357 trees per ha. The space between

the rows was utilized for growing maize plants, spaced at 2 m × 2 m (density 2500 plants/ha).

Model B: M. oleifera and Acacia auriculiformis as Tree Components

The tree species used in this model were *M. oleifera* and *Acacia auriculiformis*. Seedlings were raised in poly bags and inoculated with *Rhizobium*. The design, spacing, and density of trees was the same as in Model A. The space between rows was again utilized for growing maize at a spacing of 2 m × 2 m (2500 plants/ha).

Three one-hectare fields were maintained for each model. Seedlings were watered once per week for six months to ensure satisfactory establishment and thereafter once in a fortnight. Weeding and casualty replacement were attended to as well. Fertilizer comprised of 50 g diammonium phosphate, 50 g potash and 1 kg of farmyard manure was applied in two dosages. Data were analyzed by ANOVA or T-test, and accordingly, means were separated using Duncan's multiple range test ($\alpha < 0.05$).

RESULTS

Growth Performance

The height and basal girth (measured at soil surface) of all three tree species in models A and B were recorded periodically and the results at the end of third year are displayed in Table 1. The average height of *M. oleifera* at this point was 280 cm and 260 cm in Models A and B, respectively, and average basal girth was 32 cm and 28 cm. There was no significant difference in the growth of *M. oleifera* between models. *C. equisetifolia* attained an average height of 670 cm and girth of 28 cm within a three year period and *A. auriculiformis* attained a height of 680 cm and girth of 32 cm.

Yield and Returns from M. oleifera

M. oleifera started flowering at the age of 4 months and yielded 15 to 20 pods per tree. The number of pods harvested during the second season was three to four times greater than the first harvest. With periodical cultural operations and maintenance, the trees continued to yield almost

TABLE 1. Growth Performance of Trees in Different Models in Agroforestry System (Age 3 Years)

Species	Height (cm) Mean±SE	Basal girth (cm) Mean±SE
Model A		
M. oelifera	280±7.8b	32±2.4b
C. equisetifolia	670±10.1c	28±5.8a
Model B		
M. oleifera	260±8.5a	28±1.8a
A. auriculiformis	680±13.8c	32±6.9b

Means followed by same letter do not significantly ($P < 0.05$) differ according to Duncan's multiple range test (DMRT).

TABLE 2. Yield from *M. oleifera* Over a Period of 3 Years

System	No. of Pods/ha Mean±SE
Model A	68,250±230b
Model B	61,750±138a

Means followed by same letter do not significantly ($P < 0.05$) differ according to Duncans multiple range test (DMRT).

the same number of pods during the third year (Table 2). Thereafter the production declined. More pods were harvested when *M. oleifera* was interplanted with *C. equisetifolia* (68.250±230) than with *A. auriculiformis* (61.750±158). As per the market survey, pods are sold at the rate of Rs. 60 per 100, resulting in a gross income of Rs. 40,950 and Rs. 37,050 per hectare over a period of three years for Models A and B, respectively (Table 3).

Yield and Return from C. equisetifolia

From the harvesting of three year-old *C. equisetifolia*, 1.30 tons of fuel wood per ha was obtained. The net income from *C. equisetifolia* interplanted with *M. oleifera* amounted to Rs. 14,966/ha. Table 3 details the cost of pods, fuel wood, expenditure for growing and harvesting, etc.

Yield and Returns from A. auriculiformis

A. auriculiformis was harvested for fuel wood at the end of third year; 10.6 tons of fuel wood was obtained per hectare, amounting to a net in-

TABLE 3. Model A: Economic Returns from *M. oleifera*, *C. equisetifolia* and *Maize* Models

Economic Returns (36 months)		
***M. oleifera*:**		
Number of trees	325	
Number of pods	68,250	
Cost of pods @ 60 per 100 (Rs.)	40,950	
Expenditure (Rs.)	2,895	
Net Income (Rs.)	38,055	
Average net income (Rs./ha/yr)	.....	12,685
***C. equisetifolia*:**		
Number of poles	325	
Fuel wood material (t/ha)	1.3	
Cost of poles @ Rs. 45 per pole	14,625	
Cost of fuel @ Rs. 1,700/t	2,210	
Expenditure (Rs.)	1,869	
Net Income (Rs.)	14,966	
Average net income (Rs./ha/yr)	.....	4,988
Agri. Crop (*Maize*):		
Grain Yield in tons (3 Years)	6	
Cost @ Rs. 4000/t	24,000	
Expenditure (Rs.)	7,500	
Net Income (Rs.)	16,500	
Average net income (Rs./ha/yr)	.....	5,500
Total net income (Rs./ha/yr)		**23,173**

come amount of Rs. 14,031. The details of cost of planting, pruning, harvesting, etc., are given in Table 4.

Yield and Returns from Maize

The grain yield of the maize intercrop harvested at the end of the third year was significantly higher in Model A (6 tons/ha) than in Model B (3.5 tons/ha). Maize economic returns are detailed in Tables 3 and 4. The average net income was Rs. 5,500 in Model A and Rs. 3,266 in Model B.

DISCUSSION

Economic issues in agroforestry systems have received considerable attention lately (Arnold, 1983; Hoekstra, 1985). Complicating factors

TABLE 4. Model B: Economic Returns from *M. oleifera*, *A. auriculiformis* and *Maize*

Economic Returns (36 months)		
M. oleifera:		
Number of trees	325	
Number of pods	61,750	
Cost of pods @ 60 per 100 (Rs.)	37,050	
Expenditure (Rs.)	2.895	
Net Income (Rs.)	34,155	
Average net income (Rs./ha/yr)	.....	11,385
A. auriculiformis:		
Number of trees	325	
Fuel wood (t/ha)	10.6	
Cost of fuelwood @ Rs. 1,500/t	15,990	
Expenditure (Rs.)	1,869	
Net Income (Rs.)	14,031	
Average net income (Rs./ha/yr)	.....	4,677
Agri. Crop (*Maize*):		
Grain Yield in tons (3 Years)	3.5	
Cost @ Rs. 4000/t	14,000	
Expenditure (Rs.)	4,200	
Net Income (Rs.)	9,800	
Average net income (Rs./ha/yr)	.....	3,266
Total net income (Rs./ha/yr)		**19,328**

that must be considered include supply and demand, land-use policies, and market forces (ICFRE, 1996a, 1996b). In this study, the total net income was higher (Rs. 23,173) in Model A (*M. oleifera–C. equisetifolia*–maize) than in Model B (*M. oleifera–A. auriculiformis*–maize, Rs. 19,328). This is more than that is obtained from pure plantations *C. equisetifolia* and *A. auriculiformis* (Krishnamurthy, 1989; Nadgounda et al., 1997). Similarly, high cash returns resulted from trees planted in farm forestry and agroforestry (Jain, 1988; Singh, 1988; Patel, 1988).

The space between rows of trees can be effectively used to raise agricultural crops up to a period of three years without any significant reduction in yield. A cost-benefit analysis of Model A (Table 5) and Model B (Table 6) indicates that the cost benefit ratio (B/C) of Model B exceeds 2.1, an excellent financial result. The B/C ratio for other cash crops, such as turmeric, groundnut, and cotton was only 1:2 (Jain, 1988;

TABLE 5. Cost-Benefit Analysis for *M. oleifera*, *C. equisetifolia* and *Maize* Model (Model A)

Species	Cost Rs.	Benefit Rs.	Present Value Under Different Discount Rates					
			(12%)		(14%)		(16%)	
			Cost	Benefit	Cost	Benefit	Cost	Benefit
	(Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)
M. oleifera	2,895	12,685	2,548	11,163	2,490	10,910	2,432	10,656
C. equisetifolia	1,869	4,988	1,645	4,390	1,608	4,290	1,570	4,190
Maize	7,500	5,500	6,600	4,840	6,450	4,730	6,300	4,620
Total	**12,264**	**23,173**	**10,793**	**20,393**	**10,548**	**19,930**	**10,302**	**19,466**

Discount rates 12% B/C ratio 1.88; 14% B/C ratio 1.88; 16% B/C ratio 1.88
1 USD = Rs. 46.00

TABLE 6. Cost-Benefit Analysis for *M. oleifera*, *A. auriculiformis* and *Maize* Model (Model B)

Species	Cost Rs.	Benefit Rs.	Present Value Under Different Discount Rates					
			(12%)		(14%)		(16%)	
			Cost	Benefit	Cost	Benefit	Cost	Benefit
	(Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)
M. oleifera	2,895	11,385	2,548	10,019	2,490	9,792	2,432	9,564
A. auriculiformis	1,869	4,677	1,645	4,166	1,608	4,028	1,570	3,929
Maize	4,200	3,266	3,696	2,875	3,612	2,809	3,528	2,744
Total	**8,964**	**19,328**	**7,889**	**17,010**	**7,710**	**16,628**	**7,530**	**16,237**

Discount rates 12% B/C ratio 2.15; 14% B/C ratio 2.15; 16% B/C ratio 2.15
1 USD = Rs. 46.00

Saxena, 1989; Saha and Elias, 1993) and 1:51 for bamboo at a 14 or 16 per cent discount rate (Shanmughavel, 1993).

The results of this investigation indicate that these experimental models can easily be transferred to the field for the production of food, fuel, fodder and small timber. The average annual net incomes obtained in both mixed-planting models were more than that obtained from pure agriculture. These findings are in line with the studies of Singh et al. (1987), Shankaranarajayan et al. (1987) and Reddy and Sudha (1988). Both models provide food, fuel, fodder and small timber in addition to employment for rural populations.

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Certification Moves Ahead In Leaps and Bounds in Latin America

operations are formalized, Latin America will come to represent one of FSC's most robust areas of operations.

And with FSC's endorsement of Peru's standard for the non-timber forest product *Bertholletia Excelsa*, commonly known as Brazil, or Amazon, Nuts, small forest owners in Peru who harvest Brazil nuts have now have a new advantage as their products reach the marketplace: the worldwide recognition and acceptance of the FSC's "checkmark and tree" logo.

TREATMENTS TO ENHANCE DURABILITY OF BAMBOO IN SERVICE – A REVIEW

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ABSTRACT

Bamboo is non-durable as it is liable to attack by fungi and also susceptible to attack by insects. Hence bamboo is subject to different treatment methods to enhance its durability. Bamboo is used for a variety of purposes and has gained renewed importance in the present day context of shortage of wood due to its fast growing character. This paper mainly reviews different treatment methods practiced now days.

INTRODUCTION

Bamboo has been traditionally in used from time immemorial, the important uses was being housing, scaffolding, ladder, fence post, tent pole, bridges, bullock cart and agricultural implements. However, bamboo is non durable as it is liable to attack by fungi (brown-rot, white-rot, soft-rot and moulds) and also susceptible to attack by insects (termites and borers). As its natural durability is low, the service life of structure made from it is often short. However, by treating the bamboo, its service life can be extended. An attempt has been made to review the different treatments methods (traditional and non-traditional) to enhance durability of bamboo in service, and is reported in this paper.

METHODS OF TREATMENTS

Generally, the treatment of bamboo is divided into two categories, viz., (a) treatment of green bamboos and (b) treatment of dry bamboos. In addition to the established methods of treatment for wood, some traditional methods are also in use for the treatment of bamboos (Anon, 1945,1961,1981,Casin and Mosteiro, 1970). Such methods include leaching in water and white washing, and can be carried out without special equipment and technical know-how. Chemical preservation, on the Narayanamurthi et at., 1947 other hand, needs skill and a definite treatment schedule.

A. Traditional (non-chemical) methods of protection

Controlling starch content in felled bamboos

In bamboos, soluble sugars are the principal nutrients for parasites. Thus, bamboos with depleted carbohydrates become reasonably resistant to the attack of borers and staining; fungi. Methods adopted for lowering the sugar content in bamboos are:

(1) Felling of bamboos during low-sugar content season: -

Sugar content in almost all plants varies with seasons. In India, for example, it is higher in spring than in winter (Purushotham 1963) . Therefore, it is advisable to harvest bamboos between August and December.

(2) Felling of bamboo at maturity when sugar content is low: -

Sugar content in bamboos varies with age. It is lowest during the first year but felling of one-year –old bamboo is not desirable because of very low strength and yield. Normally, bamboo matures at 3-4 years.

(3) Post- harvesting transpiration of bamboo culm: -

Sugar content in bamboos can also be reduced by keeping culms upright or leaning them against trees for a few days. Parenchyma cells in plants continue to live for some time, even after felling. During this period, the stored food materials are utilized and, thus, the sugar/ starch content in bamboos is lowered.

(4) Water soaking of bamboo: -

In Indonesia, Vietnam and Africa, an easy and widely followed practice for increasing the durability of bamboo is soaking bamboo in water (sulthoni, 1987). During soaking in water, most of the sap present in bamboo is leached out. Some workers have suggested that a soaking period of 4 to 12 weeks is sufficient. Experimental work on submerging in mud (Suhirman, 1987; Sulthoni, 1990) and other applications of water soaking have not yet resulted in additional recommendations.

Baking over open fire

Baking over fire after applying oil on the surface is another traditional method for preservation of green round bamboos. This causes rapid drying of the outer shell and induces partial charring and decomposition of starch and other sugars. Moist heating is reported to cause irreversible swelling in bamboo, which probably balances the shrinkage due to moisture loss, thus stabilizing bamboo. Baking is recommended over a gentle fire, taking care that the surfaces are rotated constantly. Excessive heating/ drying can cause severe collapse (Rehman and Ishaq, 1947). This method is very useful for simultaneous straightening of bamboos in round form.

Lime washing and other coatings

A variety of coatings, such as tar, lime wash, tar and lime wash and tar sprinkled with sand, are used by house builders in Indonesia. These coatings are successful only when continuously applied at cut surfaces, exposed internodes, abrasions and splits.

B. Chemical Preservative Treatment Methods

Chemical protection ensures a longer life for bamboos. Treatments can be given using a variety of chemicals, depending upon the culm condition (green or dry) and ultimate use to which the material is to be put. Both non-pressure and pressure treatment processes can be used effectively, the key being though penetration and distribution with recommended doses of preservatives. Penetration of chemicals can be checked by simple spot tests. Following usual laboratory analysis techniques recommended for different wood preservatives can do assay of preservative.

Treatability of Bamboo

The tissue of bamboos is built up of parencymatous cells and vascular bundles (vessels and thick-walled fibers). The vascular bundles are not uniformly distributed inside the culm. Numerous smaller ones are present towards the outer portion, while larger but fewer bundles are found towards the central part of the culm (Kumar and Dobriyal, 1992). Bamboo has no radial cell elements like the rays in wood. The outer wall is covered by a thin and hard layer and is lees permeable than the inner layer. Nutrients are stored in the ground tissue of parenchyma cells, which constitute up to 50% of the tissue

(Liese, 1987). Bamboos behave entirely differently from wood during treatment with preservative.

The vascular bundles play and important role in preservative treatment. The axial flow is quite rapid in green bamboos, because of the end-to-end alignment of vessels. The degree of penetration decreases as the distance from the conducting vessel increases. The larger vessels tend to get a larger amount of preservative than the smaller vessels. (Both larger and smaller vessels belong; to Mata xylem whereas the prototype consists of tracheid-like elements). Since vessels occupy a mere 10% of the culm column, the penetration of preservatives to other tissues surrounding the vessels assumes more importance because untreated pockets, especially in parenchyma tissues, can lead to early destruction by fungi (Liese, 1959).

Moisture has a great influence on tractability of bamboo, especially in the green condition, where the movement of the preservative occurs via diffusion. For a Boucherie treatment, high moisture content is conditional. Treatability is thus regulated by age (6-9 years old bamboos contain less moisture than young bamboos of 3-4 years), season of felling (maximum moisture is present during the rainy season), and position (the upper portion of the culm has always a lower moisture content than the bottom). Such differences are of great consequences in uniform and adequate treatment of bamboos by no-pressure methods (Liese, 1959).

During drying, a number of anatomical changes occur, which reduce the treat ability of bamboo. In contrast to wood, bamboo starts shrinking from the moment it starts losing water. Sap in the vessels is precipitated. Clogging the openings to the adjacent tissues. The pit canals in the parenchyma cells become covered with protoplasmic substances, rendering them somewhat less permeable to fluids. The entrapped air in various tissues increases their interfacial tension between the penetrating fluids, restricting the flow. The epidermal layers containing waxy and siliceous material repel incoming preservative solutions.

Although the anatomical structure of some bamboos has been well studied, there are not many studies on the flow channels and distribution of the preservative chemicals in different structural parts in dry bamboo. However, it

appears that diffusion across the wall decreases with increasing wall thickness. Diffusion rates are highest in the longitudinal and lowest in the radial direction (Basins and Kumar, 1978).

Recently, a study conducted on *Dendrocalamus strictus* using organic and inorganic chemicals to determine the flow paths showed that creosote was netter distributed than water soluble inorganic chemicals (Kumar and Dobriyal, 1992). Similar studies on some other species indicated that parenchyma cells are not easily penetrated in bamboos, owing to deposits of protoplasm tic substances, as mentioned above. Studs have indicated that there is variation intractability of bamboo along the wall thickness as well as height- (Table 1).

C. Treatment of Fresh Bamboo

Traditional methods increase the resistance of bamboos to borer attack but are ineffective against termites and fungi. Moreover, such methods are best suited to a small-scale user, who is as well a producer. Since bamboos have a large variety of uses and are required throughout the year, traditional methods are of

Table 1:- Preservative (CCA) loading variation along wall thinness and height in *Dendracalumus strictus*

Bamboo internode	Location along wall thickness	Specific gravity	Split Absorption Kg/m^3	Solid Absorption Kg/m^3
Base	Outer	0.674	9.8	
	Middle	0.567	9.0	8.6
	Inner	0.542	11.4	
	Average	0.594	10.1	
Middle	Outer	0.716	13.2	
	Middle	0.519	15.3	12.8
	Inner	0.522	15.4	
	Average	0.586	14.6	
Top	Outer	0.704	13.7	
	Middle	0.482	15.7	13.6
	Inner	0.450	15.3	
	Average	0.545	14.9	

Variation along wall thickness

Outer = 12.2 Kg/m^3

Middle = 13.3 Kg/m^3

Inner = 14.0 Kg/m^3

limited value. Alternatives to these methods are treatments with chemical preservatives.

(i) Steeping: - Freshly cut culms are immediately placed upright in containers of concentrated solutions of water-borne preservatives (5-10"%). The butt end, up to 25 cm, is kept immersed in the preservatives solution. Generally, drops of preservative solutions are observed at the nodes. The treatment takes between 7 and 14 days, depending on the length of the culm. Losses in preservatives solution in the container are made up to maintain the initial level of solution. Bamboos can be satisfactorily treated by this method without any equipment and technical skill (Singh and Tewari, 1980).

(ii) Sap displacement: - Round, half, quarter and 1/8 split fresh bamboos are immersed vertically up to 25 cm, in 10% aqueous solutions of water-borne wood preservatives, i.e. boric acid-borax, acid-copper-chrome, copper-chrome-arsenic, etc., in suitable containers. The preservative solution rises by wick action as the sap is sucked up. Solution level is maintained by adding fresh

quantity at intervals. Adequate loading exceeding 10Kg/m^3 are obtainable in two meter long bamboos in just six days (Singh and Tewari, 1980). Longer pieces can be treated over a slightly longer period.

In many cases, such treatments are not favored because of environmental pollution.

(iii) Diffusion process: - In the diffusion process, freshly felled culms or bamboos with high moisture content (above 50%) are kept submerged in solution of water-borne preservatives for a period of 10 to 20 days is satisfactory. The absorption and penetration of the chemicals is more in split than in round bamboo. The outer layer of bamboo is more or less impervious bamboo. The outer layer of bamboo is more or less impervious and the inner cuticle is permeable to diffusing ions (Singh and Tewari, 1981a). Therefore, boring holes near the nodes or increasing the diffusion time results in better penetration and higher loading. Preservatives that fix slowly, or have higher diffusion coefficients like boron-based preservatives, penetrate better. Dip diffusion, steaming-quenching followed by diffusion, and double diffusion, are all variations of the diffusion process.

Experiments have shown the effects of dip diffusion. For instance, diffusion with copper soleplate solution (20%) for 96 hours followed by dipping in sodium dichromate solution (20%) for 96 hours, a do then storing the bamboos under non-drying conditions of for one month, result in over 40% penetration with loading around 13 Kg/m^3 in *Dendrocalamus strictus* (Singh and Tewari, 1981b).

Steaming and quenching, followed by diffusion under drying conditions, is another variation of the diffusion process but this is still only experimental and not yet applied widely, Steaming bamboos at about 100° C for 2.5 hours and quenching in 20% solution of water-borne wood preservatives (CCA), and subsequent storage for about one month, lead to almost complete penetration with very high split bamboos is 60 percent higher than in round bamboos (Singh and Tewari, 1981b). It is, therefore, recommended that in round bamboos, if this method is to be applied, that either the septa should be punctured, or small notches should be made near the nodes, to allow free access of the solution to the inner epidermis layer of the bamboo, enabling

subsequent drainage of the inner epidermis layer of the bamboo, enabling subsequent drainage of the preservative solution from the culm. Treatment with 8-10% solution of CCA, ACC or CCB following the above schedule would give retention of about 10-12 kg/m^3 in most bamboo species.

Diffusion rates almost double with every 10-20° C rise in temperature (Kumar and Bains, 1979). However, CCA, ACC, or CCB solutions start precipitating on heating. Diffusion rates also depend on the nature of the diffusing ion and its interaction with the diffusion media. Preservatives based on ammoniac solution not only diffuse faster, but can also be heated to get better penetration and loading in shorter periods (Dec et al, 1991). Ammonical - copper-arsenite can be used for treating green bamboos by diffusion, taking advantage of better penetration of the ammonium ions.

Results of investigation, summarized in Table 2, have demonstrated that diffusion processes are perhaps the best and simples for treatment of green, split and round bamboos. Infect, these could be universally specified as preservative treatments of bamboos for all purposes.

(v) Boucherie process: - This is a widely recognized process which does not require detailed description here. It is suitable for freshly felled green bamboos with branches and leaves intact. Just chopping off about 15 cm from the butt end can treat even one-day-old bamboos. In the process, the preservatives pushed through the bamboo by gravity from a container placed at a height. This method has been modified to use a simple hand pump by means of which air pressures of 1.0 to 1.4 kg/cm^2 could

Table 2 Treatment of green *Dendocalamus strictus* by different non-pressure methods (Singh and Tewari 1979, 1981)

Specimen type	method	preservative	Duration	Absorption Kg/m^2*
Round	Diffusion	ACC6%	10Days	7.76
Half-split	,,	,,	,,	11.16
Round	,,	,,	,,	10.65
Half-split	,,	,,	,,	15.53
Round	,,	,,	30Days	15.65
Half-split	,,	,,	,,	19.77
Round	,,	Boric acid Borax 6%	10 days	7.73
Half-split	,,	,,	,,	11.32
Round	,,	,,	20 days	10.86
Half-split	,,	,,	,,	20.16
Round	Osmo-paste Diffusion	CCA paste	30 days	10.74
Half-split	,,	,,	,,	14.66
Round	,,	,,	,,	20.38
Half-split	,,	,,	,,	31.76
Round	,,	ACC paste	30 days	12.04
Half-split	,,	,,	,,	18.51
Round	,,	,,	60 days	26.25
Half-split	,,	,,	,,	31.56
Round	Steam Quenching	CCA 20%	4h/0.5 h	5.26
Half-split	,,	,,	,,	5.84
Round	,,	,,	4h/48 h	18.34
Half-–split	,,	,,	,,	30.46

* ascertained by chemical analysis

be applied to the preservatives in a suitable container kept at the ground level (Purushotam et al, 1954). This reduces the period of treatment significantly. The penetration and absorption the preservative depend upon several factors like concentration of solution, treatment time, nature of chemical used, dimensions of bamboo, its age and moisture content.

It usually takes 30-60 min to treat short bamboo lengths using pressures up to 2 kg /cm^2. the equipment at the Forest Research Institute, Dehra Dun and used for the past 35 years. Earlier studies on a number of bamboo species indicated that treatability of green bamboos with non-pressure methods was highly variable. The modified Boucherie process is a process, which can be used with confidence (Purushotham et al, 1954).

In order to get more uniform distribution of preservative from bottom to top, it is possible to use initially a concentrated solution (~6%) until the solution appears at the dripping end. This should be followed by pumping in a solution of a lower concentration (~2%) for the same period (Shukla et al, 1979).

C. Treatment of Dry Bamboo

(i) Soaking: - Air-dried bamboos have only to be submerged in the preservative solution (oil or solvent type) for a period depending upon the species, age, thickness and absorption required. Such treatments are used in India, but not elsewhere. The penetration is predominantly by capillarity. The soaking method requires little equipment and technical knowledge, provided the schedule of treatment, such of dripping, is worked out. Nonetheless, there are dangers of pollution due to spillage.

If water-borne preservatives are used, the process is called "Steeping". Results of investigations using specimens of *D. strictus* and *B. ploymorpha* soaked in water-soluble preservatives (5% CCA composition) indicated that the penetration of the solution was fast in the initial stages and gradually slowed with time. Adequate amount of preservatives, however, were absorbed in all the specimens in about two seeks. The absorption of preservative was n\more in half-round specimens in comparison to round ones (Table-3).

Table 3. Absorption of preservative in air-dried specimens of *Dendrocalamus strictus* and *Bambusa polymorpha* treated by steeping in 5% CCA composition.

Species	Type of Sample	Dry salt absorbed (kg/m^3 after different immersion period (days) 6	12
Dendrocalamus strictus	Round	9.75	13.15
	Half-split	9.71	14.43
Bambusa polymorpha	Round	6.93	10.01
	Half-split	13.44	17.92

Soaking treatments with organic solvent type preservatives, such as pentacholorophenol, copper/ zincnapthenates /abietates, work better than steeping in water-soluble preservatives. Such treatments may, however, be more expensive in some countries because of the cost of the solvents. Cold

soaking in diesel oil for 7days, reported to prevent borer attack, works out to be cheaper than treatment with copper-sulphate solution in Indonesia (Sulthoni, 1990).

Results above are experimental and if he process becomes more widespread, practical application such as moisture contents and length of samples need to be worked out.

(i) Hot-cold process: - At FRI, Dehra Dun, hot-cold tank process has been developed. However, it is not widely in use elsewhere due to the economic aspects. Air-dried material is loaded in the tank fitted with steam coils or more some other heating arrangement. The tank is then filled with a hot creosote fuel oil mixture and heating is continued to raise the temperature to about 90°C, which is maintained for a period of about 3-6 hours. The preservatives it then allowed to cool, after which oil is drained out. The round bamboos with holes are then kept inverted in the tank, to allow the preservatives to flow out from the hollow portions of the bamboo. Split bamboos do not require such a practice.

Typical loading of creosote: fuel oil obtained following different heating schedules are reported in Table 4

Table 4. Hot-cold tank treatment of bamboos (without holes with cresote : fuel oil (1:1) (Singh and Tewari,1979).

Species	heating time (h)	absorption(kg/m) Round	Half-split
Dendracalamus strictus	3	54	57
	4	69	72
	6	72	74
Bambusa polymorpha	3	42	45
	4	49	57
	6	67	71

(i) Pressure treatment : - It is theoretically possible to use pressure treatment (Purushotham, 1963, Kumar and Dobriyal, 1992) but general applicability in a number of countries has not yet been developed, Species of bamboos having thin walls are susceptible to cracking, even when treated under low pressure

(5-7Kg/cm^2) (Singh, 1976). Round and half split bamboos of thick walled species like *Dendrocalamus strictus* can be treated with creosote: fuel oil (1:1) under hydraulic pressure of 14KG/ cm^2. Retentions ranging between 88 and 92kg/m^3 are obtainable in round or half split bamboos (sign and Tewari 1980).

Treatment with water- borne preservatives like CCA can also be done effectively. A pressure of 3.5kg/cm^2 for one hour sufficient to achieve retention of more than 8 Kg/m^3 (drysalt) in split bamboos. (Kumar and Dobriyal, 1990). The preservative loading varies significantly from bottom to top (Increase) and from inner layers to outer layers (decrease). Treatment with 6% CCA under 7 Kg/cm^2 yielded absorptions between 14-18 kg/m^3 (Singh and Tewari 1980).

The problem of collapse of round bamboos under pressure treatment can be solved by drilling holes or notches between septa (Sonti, 1990), but this leads to considerable spillage. Drilling holes not only equilibrates the pressure on both sides of the bamboo wall, but also ensures better treatment from both surfaces. A vacuum/pressure schedule helps to ensure more uniform penetration.

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ADVANTAGES AND DISADVANTAGES OF DIFFERENT METHODS OF TREATMENT OF BAMBOO

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ABSTRACT

An attempt has been made to distinguish the advantages and disadvantages of different treatment methods of bamboo and the same is presented.

INTRODUCTION

Bamboo play a dominant role as woody raw material for a variety of products. However, bamboo is non-durable as it is liable to attack by fungi and insects. So, several methods are employed to enhance its durability. This paper mainly deals with the advantages and disadvantages of different methods of treatment.

Treatment of Bamboo

Treatment of Green (Fresh) Bamboo

Treatment of dry Bamboo

Traditional (Non – Chemical) Methods

(i) Felling of bamboo during low-sugar content season
(ii) Felling of bamboo at maturity when sugar content is low
(iii) Post-harvesting transpiration of bamboo culm
(iv) Water soaking of bamboo
(v) Lime washing and other coatings

Advantages

Disadvantages

Without special equipment and technical know – how	1) Not applicable to all ages of Bamboos. 2) Treatment schedule can't be done 3) Treatment of Green Bamboo can be applicable

B) Backing over open fire

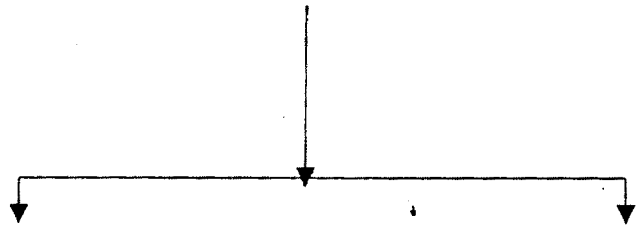
Advantages

Very useful for simultaneous straightening of bamboo in round form.

Disadvantages

Excessive heating /drying can cause severe collapse.

II. Chemical Preservation



Advantages	Disadvantages
1) Ensures longer life for Bamboos 2) Can be applicable for both green/ Bamboos	Needs skill & a definite treatment schedule.

Treatment of Fresh Bamboo

A) (i) Steeping
(ii)Sap displacement
(iii) Diffusion process
(iv) Boucherie process

Advantages :-

(1) Bamboos can be satisfactorily treated by this method without any equipment and technical skill.

(2) Round, half, quarter and 1/8 split fresh bamboos can be treated.

Disadvantages:-

1) Ineffective against termites and fungi
2) Traditional methods are of limited value.
3) Not favored because of environmental problem,

Treatment of dry Bamboo

(1) Soaking: -

Advantages

1. Bamboos can be satisfactorily treated by this method without any equipment and technical skill.

Disadvantages: -

1) Soaking method requires little equipment and technical knowledge, provided the schedule of treatment such as type of preservation, its concentration and the period of dipping is worked out.
2) Danger of pollution due to spillage.

(II) Hot – Cold Process:

Advantage

(1) Both round and split bamboo can be treated.

Disadvantages

(1) It is not widely in use due to the economic aspects.

(III) Pressure Treatment: -

Advantages: -

(1) Treatment with water- borne preservatives likes CCA can be done effectively.

Disadvantages: -

(1) It is theoretically possible to use pressure treatment but general applicability in a number of countries has not yet been developed.
(2) The problem of collapse of round bamboo under pressure treatment.

Environmental Aspects of treating Bamboos with Preservatives

Methods of traditional (non-chemical) techniques are absolutely safe and pose no threat of environmental pollution. At the same time, these methods have limited tope in extending bamboo's service life.

Chemical preservation strategies employ chemicals toxic to fungi and insects and are invariably toxic to mammals. Slight carelessness in the use of such chemicals can endanger the safety of workers handling the chemicals on freshly treated material.

Although the preservatives recommended for bamboo have long safety records, here chemicals are under constant security by various pollution control agencies. The very name of arsenic in preservative formulation raises an alarm in the minds of environmentalists. Formulations containing arsenic and chromium have been rigorously tested for leaching in laboratory and under service conditions and meet current safety standards. CCA treated materials is considered absolutely safe and has been recommended for the treatment of play ground equipment. Such formulations make complexes with wood substance and are rendered immobile to cause any toxicity concern. Pollution hazards do exist at formulation as well as impregnation sites. It is suggested that ready-to-use premixed formulations be used to eliminate such hazards and necessary safety precautions as suggested by the manufactures be followed. Treatment effluents, if generated on a large sachem should be adequately treated before disposal.

Pentachlorophenol is another chemical being viewed cautiously. The present technology of manufacture of this compound claims that no dioxins are produced in the process. Nevertheless, disposal of all treated wood products and residues have to meet the toxicity characteristic leaching produced limits (TCLP) proposed by the Environmental Protection Agency (EPA) of the USA.

Boric - acid: borax, Cu/Zn naphthenates / abietates are among the safest wood preservatives being promoted the world over. Many new chemicals considered to be environmentally safe such as Tebyconazole, IOBC (3-iodo 2 – propany1 butyl carbonate), chloro-thalonil, isothiozolones and synthetic pyrethroides are under various tag of adoption as wood preservatives. A part from being expensive such chemical need to be tested for their efficacy on bamboos.

Disposal of preservative treated bamboo after prolonged service causes problems in several countries. In some, it is not considered a hazardous waste, but in others it has to be brought to special dumping places.

Proper safety garments such as gloves, aprons, and eye protective glasses should be used while handling preservative solutions of freshly treated materials. Any spillage of chemicals should be immediately attended to by soaking in wood dust and disposed appropriately. Freshly treated materials should be store under cover during drying to avoid rain leaching of chemicals.

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BAMBOO SHOOTS AS FOOD

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Bamboos are perennial arborescent grasses classified as minor forest produce belonging to the family Gramineae,Bamboo plays an essential role in the daily life of people in the tropical and subtropical regions. Most bamboo species produce edible shoots. These are the young culms harvested at the time of, (or) shortly after, their appearance above the soil surface (Plate1). The shoots vary in size and quality and most commercially marketed shoots are derived from a small number of preferred species (El Bassam, 1998, INBAR, 1997). Those species mainly originate from China, Taiwan, Thailand, Japan and Korea where bamboo shoots, as important constituents of Stir – fry cuisine and specialized recipes, are produced and consumed in great quantities. (Jong *et.al.*1989, IFAR, 1991).

India is one of the leading countries of the World, second only to China, in bamboo production with 32.3 million ton/ year. Bamboo species cover an area of around 10.03 million hectors, which contribute 12.8% of the total forest cover of the country. India ranks third i.e. next to China (300 Species), and Japan (237 species) in bamboo diversity (Shanmughavel, 1995).

More than 70 genera and 1,200 species of bamboo have been described, but only a few are grown commercially for their shoots. Those may be spilit into two groups: (1) the clumping types with short rhizomes (i.e. underground stems), botanically referred to as sympodial, and (2) the running types with long rhizomes, referred to as monopodial. The clumping types are more adapted to sub-tropical and – tropical climates and produce larger shoots (up to five

kilograms each) after mid – summer, while the runners are more adapted to cooler climates, and produce smaller shoots (usually not greater than 1.5 kilograms each) in spring (Shanmughavel, 1995). Given the range of bamboo species and their climate adaptation, species from both groups may have potential to produce culinary bamboo shoots under India's diverse environmental conditions. These species need to be identified.

Shoots as recorded as delicacies, eaten as a vegetable by the local tribals. Although scattered information is available on edible bamboo(Laha 2000, Bhatt *et. al.* 2003), no attempts have been made so far to evaluate the chemical composition of edible bamboos of TamilNadu. Our studies revealed that, besides being delicious, bamboo shoot (*Bambusa bambos, Phyllostachys edulis* and *Dendrocalamus strictus*) is a food rich in nutrition.

What does an edible young, shoot contain?

Water	-	89-93 g
Fat	-	03-0.4g
Fibre	-	0.5-0.77g
Calcium	-	81-96mg
Iron	-	0.5-1.7mg
Vitamin C	-	3.2-5.7mg
Protein	-	1.3-2.3g
Carbohydrates	-	4.2-6.1g
Ash	-	0.7-1.2g
Phosphorus	-	42-59mg
Vitamin B_1	-	0.07-0.14mg
Glucose	-	1.8-4.1g

The energy value per 100 g of young, shoot is 118-197 joules.

In our country , edible bamboo is yet to popular. Besides selection of appropriate species, other constraints to establishment of a edible bamboo

industry in India are the lack of suitably tested propagation techniques to improve availability of planting material, and the non-existence of relevant information on cultural manipulation of the crop under Indian conditions to achieve good yields of quality shoots. Varietal selection may be effective in overcoming temperature stress in bamboo (e.g. avoiding planting of clumping bamboo types in frost – prone areas) but other growth factors such as water and nutrients may be of overriding importance for effective – shoot production. Since no local information on the agronomy of edible bamboo is available and information from overseas relates to production in areas differing in climate and soil, specific agronomic practices such as irrigation and fertilization need to be developed for culinary bamboo shoots under Indian conditions.

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New hybrids of tuberose

TUBEROSE is an important commercial flower crop grown mainly in Karnataka, Tamil Nadu, West Bengal and parts of Maharashtra. It has immense commercial potential in floriculture trade and perfumery industry and only two varieties are under commercial cultivation — single and double.

Genetic improvement of this crop was initiated during the early Eighties at the Indian Institute of Horticultural Research Hesseraghatta, near Bangalore. After a decade of research, two superior hybrids, one each of single and double type have been developed. Named 'Shringar' and 'Suvasini' these were released recently and evaluated in farmers' field around Bangalore and were well accepted by farmers for their superiority in terms of flower quality and yield.

Shringar hybrid bears single type fragrant flowers on strong, medium spikes.

Suvasini is a multiwhorled (double) hybrid, the spikes of which are used as cut flower.

Shringar hybrid bears single type fragrant flowers on strong, medium spikes. The flower buds are attractive with a slightly pinkish tinge instead of greenish buds in the local 'single'. The spikes have more number of flowers and individual flowers are bigger compared to the local 'single' variety. Loose flowers of this hybrid can be used for garlands and essential oil extraction. The spikes can also be used as cut flowers. Loose flower yield of this new hybrid is 15,000 kg/ha/year which is about 40 per cent more than the local 'single' variety.

Suvasini is a multiwhorled (double) hybrid, the spikes of which are used as cut flower. The flowers are big, bold, pure white and fragrant and are borne on long spikes with elite appearance in contrast to off-white flowers of local 'double'. The number of flowers per spike is more and flower opening is uniform and consistent as compared to local 'double' variety. This yields about 1.5 lakh spikes/ha/year which is about 25 per cent more than the local 'double' variety.

Generally, tuberose is a hardy crop free from pests and diseases. Occasionally nematodes are reported to pose a serious problem which affects the yield and quality of flowers. Hence, screening of the hybrids for nematode (*Meloidogyne incognita*) resistance was undertaken and the results have shown 'Shringar' to be resistant while 'Suvasini' was found to be tolerant.

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Weed management in sugarcane based intercropping

SUGARCANE germinates completely in 60 days and takes another 90 days to cover the ground by foliage. During this period it is essential to provide a weed-free environment. Intercropping increases the competitive ability of crops and reduces weeds.

Weed reduction depends on the nature of crops and their spatial arrangement.

Experiments were conducted on five intercropping systems in sugarcane involving blackgram, soybean, bhendi, onion and maize.

Weed management practices include hand weeding thrice at 25, 55 and 85th day after planting, pre-emergence application of isoproturon at the rate of 1 kg/ha and one hand weeding on 55th day and pre emergence application of fluchoralin at the rate of 1 kg/ha and one hand weeding on 55th day along with control by weeds. An efficiency of 55.8 per cent was registered in the case of isoproturon and hand weeded plots, the manual weeding recorded 45.6 per cent.

The growth and yield parameters — number of internodes, diameter of cane length of the internodes — were higher in sugarcane-soybean intercropping than other intercropping systems.

Weed management methods with isoproturon combined with hand weeding on 55th day after planting gave an yield of 15.7 per cent more than the unweeded control.

Intercropping systems with soybean accounted an additional income of Rs. 296.2 per hectare with a cost benefit ratio of Rs. 2.11 per hectare.

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Treating water to control ciliate in shrimp

Ciliate infestation, reduces the efficiency of shrimp hatcheries as it causes mass mortality inspite of all precautions. The ciliate population is generally proportional to bacterial load in the system as the ciliates feed on bacteria. There are two ways to control ciliate infestation — water pretreatment and water quality management.

Necessary precautions are to be taken to reduce organic and bacterial load in the water that enters a hatchery. This can be done by filtration systems (biological and mechanical), UV irradiation and chlorination-dechlorination methods. An ozoniser also can be used for this purpose. Inspite of all these measures, ciliate infestation might occur. Since the excess/unfed feed can increase the bacterial load in the hatchery, optimal feeding of algae, artemia and artificial feed supplements (micro-encapsulated feeds and egg custard) is essential. If all the methods fail, the hatchery has to be treated with chemicals such as formalin or malachite green. While the early post larval stages can be treated with formalin upto 10 ppm, late post larval stages can be treated with a short duration bath (25 ppm). Drugs such as cutrine, oxytetrine and copper have also proved to control ciliates.

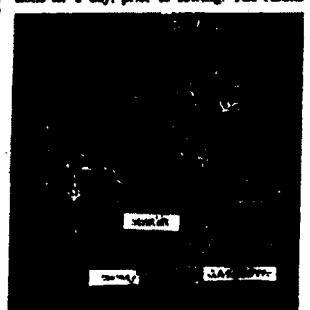
S. Felix and I. Rachel

Tamil Nadu Veterinary and Animal Science University, Madras

Enhancing germination of silver oak

Silver oak is an evergreen tree grown at moderate elevations for shade in coffee and tea plantations. As the plant is mostly seed propagated, poor germination and short life span are encountered at times. A study was carried out at the Tamil Nadu Agricultural University, Coimbatore, with three-month old seeds to study germination and vigour potential.

The seeds were soaked in water, GA_3 (100, 250 and 500 ppm), potassium nitrate and thiourea (each 1.0, 1.5 and 2.0 per cent) and a mixture of all the three (1:1:1 proportion) solutions for a day, prior to sowing. The results



should GA_3 (250 ppm) to have beneficial effects over others with 43 per cent germination against 9 per cent in control. Vigour also enhanced by six times than the control. The combination treatment showed the most best effect and thiourea had a deleterious effect.

P. Muthuswami and C. Chidambaram

Microbes to fight rice pests and diseases

From Our Agriculture Correspondent

ECOLOGICAL rice farming supports natural enemies of crop pests which include fungi, bacteria, nematodes and virus. In the absence of toxic insecticides and fungicides, these beneficial microbes proliferate and keep the population of insect pests under check.

For the Farmer's Notebook

Scientists have observed that a soil fungus, Trichoderma species, helps in controlling serious diseases of rice. Seed treatment and root-dipping with the fungal suspension acted as an inoculum.

A few nematodes, in rice fields, are known to attack pests such as brown planthopper, green leafhopper, white-backed planthopper, zigzag leafhopper, stem borer and rice caseworm.

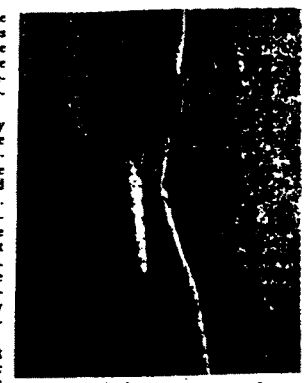
Nuclear polyhedrosis virus (NPV) also comes in handy to infect and cripple armyworm / cutworm, rice leaf folder and rice green semilooper. Scientists are attempting to culture this benign virus and use it against rice pests as part of an integrated pest management strategy.

Mycologists are seriously examining the role of *Beauveria bassiana*, commonly known as white muscardine fungus, in managing rice stemborer pest. This fungus attacks the larvae and the infected larvae turn white and get reduced to a creamy mass. The dead larvae remain stuck to the plants.

The fungal mycelium enters the larvae orally or through the soft portions. The spores of the fungus enter the host by mere contact and germinate immediately. Once inside the host, the fungus grows fast. Its rate of multiplication and spread reaches a peak during the rainy season.

Stemborer larvae affected by the fungus become dull. They do not eat properly and die. The fungus is slow-acting, and after colonisation it builds up quite fast in about a fortnight. Though, it takes four to five days to cripple the larvae, the ecological advantages of this target-specific fungus is immense. This is precisely why the scientists are evincing keen interest in employing it as a bio-control agent.

Scientists should screen and isolate virulent strains, which are safe to silkworms and specific to rice stemborer, and develop simple techniques for mass production and release in rice fields. Similar exercises have been done by scientists at the Kodagu Coffee Growers' Action Committee to isolate and mass multiply virulent strain of *Beauveria bassiana* specific to coffee berryborer.



Fungus help in controlling the larvae of rice stem borer

according to Mr. K. S. Subbiah, an expert in eco-friendly farming, technologist and chairman of the committee.

Bamboo for wasteland

Bamboo plays a significant role in rural economy due to its fast growth, easy propagation, quick maturity, good soil-binding properties and minimum requirement of input for cultivation. As a result it is classified as a quickly renewable source.

Marginal lands and areas that are not used for agricultural crops — canal banks, moist uplands, river bank and farm roadsides — can be brought under bamboo plantation. Seedlings must be planted in pits of size 45 x 45 cm at an espacement of 4 m. The upper halves of the pits are to be filled with a mixture of 25 g Vijay complex 17:17:17 per plant. Prushwood fences are to be made in each seedling to protect them from rodents, grazing and browsing animals. Seedlings were adequately irrigated at 15 day intervals.

An average culm emergence of two per clump was observed one year after planting. The average annual recruitment increased in the subsequent years and numbered at 4-13 per clump. The culms that emerged in the first year were short and thin at breast height. Culms produced in the subsequent years were taller and bigger. It was observed that an income of upto Rs. 1000/- could be got in three years from just one clump of bamboo.

P. Shanmughavel and K. Francis

Bharathiar University, Coimbatore

New variety of Korra

A new variety of Korra (foxtail millet) has recently been released by the Andhra Pradesh State Seed Sub-Committee. The variety has been developed at the Regional Agricultural Research Station, Nandyal of Andhra Pradesh Agricultural University. The new variety recorded an average grain yield of 1941 kg/ha an increase of 34 per cent over the popular Nallasuda Korra (SIA 326). The variety is 120-130 cm tall and thin stemmed. Panicles are 18-20 cm long, semi-compact covered with medium sized bristles. Seeds are densely packed and light yellow. It matures in about 85-90 days.

Kuldeep Singh Dangi

Assistant Research Officer, National Seed Project, Rajendranagar, Hyderabad

Controlling dodder in niger

CUSCUTA' hyalina, a dodder commonly known as jalandhri, swarnalata or nirmuli by tribals in Orissa, is an obnoxious weed associated with niger, *Guizotia abyssinica*, which is cultivated extensively during the rainy season in marginal to sub-marginal lands. This phanerogamatic weed can lead to as much as 50 per cent yield loss.

The cuscuta weed is stem parasite which sustains through seeds. The seeds remain dormant in the field and germinate along with niger. The weed is pernicious and under favourable conditions, it can remain viable for 15 years. Cuscuta lacks chlorophyll and derives its nourishment from the niger stem by inserting its sucking apparatus called haustoria. Within 50 days after germination, it completely entangles the niger plant rendering it unproductive.

Experiments have established that the weed

by sieving through 70-100 mesh. Avoiding niger cultivation in cuscuta infested fields, hand picking and destroying cuscuta twines three weeks after germination before fruiting also helps in controlling the weed. Application of herbicide granules like CIPC (Furloe) at the rate of 2 kg (active ingredient) per hectare, five days after germination, helps to or post-emergence spraying of herb 2 kg (active ingredient) per hectare 15 days after germination of niger control the parasite. There are many bio-control agents such as insect parasites which naturally suppress the weed growth but cannot be easily manoeuvred.

A tribal farmer of Orissa has developed a simple method to combat the weed. If in a particular year infestation by cuscuta weed is wish, then in the following year he takes a mixed crop of finger grows three to four rows of niger. This method is termed as 'border niger cultivation' or locally 'Pali Alasi' cultivation. As niger grown on the border is not browsed by cattle it prevents cattle from entering the field. Niger as an intercrop of ragi grows sturdy and usually withstands cuscuta attack.

Even if a few cuscuta infested plants are noticed, they can be weeded out. The niger seeds reaped are also free from cuscuta seeds. The field is cleaned of dormant cuscuta seeds in the following year.

Niger crop grown in this manner matures early compared to conventional sowing and also fetches a good price. By this method the land equivalent ratio (LER) increases giving a yield advantage of 25 per cent over the sole crop of ragi.

வேளாண்மணி

புதன்கிழமை, 13 நவம்பர், 1996

மூங்கில் - ஒரு கண்ணோட்டம்

பி. சண்முகவேல், கு. பிரான்சிஸ்,
தாவரவியல் துறை, பாரதியார் பல்கலைக் கழகம், கோவை.

மூங்கில் புல் இனத்தைச் சேர்ந்தது. உலகில் உள்ள மூங்கில் இனங்களில் சுமார் 125 இனங்கள் நமது நாட்டில் இயற்கையாகவே காணப்படுகின்றன. மேலும் 23 இனங்கள் மேலை நாடுகளிலிருந்து இறக்குமதி செய்யப்பட்டுள்ளன. நமது நாட்டில் 100.3 லட்சம் ஹெக்டேர் பகுதியில், அதாவது மொத்த வனப்பகுதியில் 12.8 சதம் பரவியுள்ளது. பொதுவாக மூங்கில் இனத்தில் சிறு மூங்கில் (கல் மூங்கில்), பெரு மூங்கில் என இரு வகைகள் உள்ளன. கல் மூங்கிலைத் தவிர மற்ற எல்லா மூங்கில்களும் தட்டை மூங்கில்களாகும். அதாவது கழிகளின் நடுப்பாகம் வெற்றிடமாக இருக்கும்.

வளருமிடம்

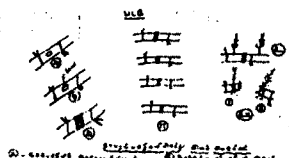
கடல் மட்டத்திலிருந்து 1000 மீட்டர் உயரமுள்ள பகுதிகளில் வளரும். ஆறு, ஓடைகளின் கரையோரங்களிலும், ஈரமான இலையுதிர் காட்டுப் பகுதிகளிலும் இவை செழித்து வளரும். சதுப்பு நிலப்பகுதிகளிலும், வயல் ஓரங்களிலும், ஈரமுற்ற தரிசு நிலப் பகுதிகளிலும் மூங்கிலை வளர்க்கலாம். ஒரளவு மழை பெறக்கூடிய, நீர்வளம் நிறைந்த பகுதிகளில் இவை செழித்து வளரும்.

மூங்கில் அதன் இனத்தைப் பொருத்து, 20 - 30 ஆண்டுகளுக்கு ஒரு முறைதான் பூக்கும் தன்மை கொண்டது. விதைகள் பெரும்பாலும் மிகச்சிறியவையாகவும், மெல்லியதாகவும் காணப்படுகின்றன. பொதுவாக மூங்கில் அழிவிருத்திக்கு விதைகள், கணுக்கள், தரை வளர்ப்பின் மூலம் பெறப்படும் நாற்றுகள் பயன்படுத்தப்படுகின்றன. விதைகள் மிகக் குறுகிய காலமே உயிர்த் தன்மை உடையது எனவே விதைகளைக் கொண்டு மூங்கில் வளர்ப்பது பெருமளவில் இல்லை. தரை வளர்ப்பின் மூலம் பெறப்படும் நாற்றுக்கள், வளர்ச்சி மையங்களில் மிகக் குறைந்த விலைக்கு கிடைக்கின்றன.

மிக விரைவில் பலன்பெற தாவரப் பகுதிகளிலிருந்து இனப் பெருக்கம் செய்து கன்றுகளைப் பெருக்கலாம். ஆனால் இதில் முக்கிய குறை என்னவென்றால் தாய்ச்செடி பூக்கும்பொழுதே கன்றுச் செடியும் பூத்து, பின்பு மடிந்து விடும். எனினும் பெரும்பாலும் இம்முறையே பின்பற்றப்படுகிறது.

இனப் பெருக்கம்

இரண்டு அல்லது மூன்று வயதுடைய தாய் நாற்றுக்களிலிருந்து கணுப்பகுதியை எடுக்கும்போது ஒவ்வொன்றிலும் முதல் கணுக்களுக்கு மேலேதான் வெட்ட வேண்டும். இரண்டு கணுக்களை உடைய தண்டுப் பகுதிகளை வெட்டி எடுத்துக் கொள்ள வேண்டும். பூக்கள் உள்ள தண்டுகளும், பூக்கும் என எதிர் பார்க்கப்படும் தண்டுகளும் தவிர்க்கப்பட வேண்டும். ஏனெனில், இவை உடனடியாகப் பூத்து, பின்பு கன்று மடிந்துவிடும். இலைகளை படத்தில் உள்ளது போல் கணுக்களுக்கு சேதம் விளைவிக்காமல் வெட்டி எடுத்து விடவும். வெட்டி எடுத்த தண்டுகளை உடனடியாக எடுத்துச் செல்ல முடியாத மற்ற காரணம் இருப்பின், வெட்டிய தண்டுகளை ஈரப்பதம் உள்ள மரத்தூளுக்கு நடுவில் வைத்துப் பாதுகாத்து பின்பு எடுத்துச் செல்லலாம். பின்பு இரண்டு கணுக்களுக்கு மத்தியில் படத்தில் காணப்படுவது போல் கூரிய கத்தியால் வெட்டிக் கொள்ளவும். வெட்டும் போது மூங்கில் வெடித்து விடாமல் பார்த்துக் கொள்வது மிகவும் முக்கியமாகும்.



இதற்கிடையில், 10 கிராம் நாப்தலின் அசிடிக் அமிலம் எடுத்து, 250 மில்லி லிட்டர் எத்தில் ஆல்கஹாலில் நன்றாகக் கரைத்துக் கொண்டு சுத்தமான பெரிய கொள்கலனில் விட்டு 100 லிட்டர் வருமாறு தண்ணீர் ஊற்றி நன்கு கலந்து கொள்ளவும். இறுதியாகக் கிடைக்கும் திரவக் கரைசல் 1000 தண்டுகளுக்குப் போதுமானதாகும்.

ஒவ்வொரு தண்டிற்கும் 100 மி.லி. வீதம் சிறிய வாய் உள்ள பாட்டில் மூலமாக, வீணாகாமல் தண்டின் வெட்டிய பகுதியில் ஊற்ற வேண்டும். ஊற்றிய பின்பு 60 செ.மீ. நீளமும், 6 செ.மீ. அகலமும் உள்ள பிளாஸ்டிக் காகிதத்தால் தண்டைப் பகுதியை இறுக்கமாக, ஊற்றப்பட்ட கரைசல் வெளியே வராமல் கட்ட வேண்டும். தண்டுகள் நாற்றங்காலுக்குக் கொண்டுவந்தவுடன் இம்முறையைக் கையாள வேண்டும்.

நாற்றங்கால் அமைப்பு

நாற்றங்கால் பகுதியில் உள்ள மண்ணை நன்றாகப் பண்படுத்தி மண், மற்றும் மணல் 3:1 என்ற விகிதத்தில் தயார் செய்து கொள்ளவேண்டும். பாத்திகள் 10 மீட்டர் X1 மீட்டர் அளவில் இருக்கலாம். நாற்றங்காலை ஒரு வாரத்திற்கு முன்பே தயார் செய்து உலர் இலைத்தழை, சருகுகளால் மற்றும் பூச்சிகளை தவிர்க்க பூச்சிக் கொல்லி மருந்து (ஆல்டிரின்), காளான் கொல்லி (பாவிஸ்டின்) தெளிக்க வேண்டும். ஒவ்வொரு பாத்திக்கும் 40 லிட்டர் ஆல்டிரினும் (0.015 சதம்) 30 லிட்டர் பாவிஸ்டின் (0.05 சதம்) தண்ணீரில் கலந்து தெளிக்கவும்.

தண்டுகளை இடைநிலையில், துளை செய்யப்பட்ட பகுதி மேல் நோக்கியவாறு மண்ணில் பதிக்க வேண்டும். 50 - 60 தண்டுப் பகுதிகள் ஒரு பாத்தியில் வருமாறு அமைக்க வேண்டும். பின்பு தண்டுகளின் மேல் பாகம் தெரியும்படி மிதமாக மண் தூவி விடவும். இந்தப் பாத்திகளின் மேல் கூரை அமைப்பது மிகவும் அவசியம். ஏனெனில், சூரியக் கதிர்கள் நாற்றுகளை நேராகத் தாக்காமல் தண்டுகள் காக்கப்படுவது மிகவும் முக்கியம். இந்தக் கூரையை மழைக்காலம் ஆரம்பிக்கும் முன்பு எடுத்து விடவேண்டும். இந்த நாற்றங்காலில் காலை, மாலை இரு நேரங்களிலும் தண்ணீர் தெளிக்க வேண்டும். தண்ணீர் தேங்காமல் பார்த்துக் கொள்வது மிகவும் அவசியம். ஜூன், ஜூலை மாதங்களில் முளைத்த தண்டுகளை வேர் பகுதியோடு தோண்டி எடுத்து இரண்டு கணுக்களுக்கும் நடுவில் மிகக் கவனமாக வெட்டி இரண்டு தனித்தனிக் கன்றுகளாகவும் நிலத்தில் நடலாம்.

முளைத்த தண்டுகளை X 5 மீட்டர் இடைவெளியில் நட வேண்டும். தினமும் காலை மாலை வேளைகளில் நீர் பாய்ச்ச வேண்டும். சுமார் ஆறு மாதங்களுக்குப் பின்னர் 15 நாட்களுக்கு ஒருமுறை நீர் பாய்ச்சுதல் போதுமானது. மண்ணில் ஈரப்பதம் இருப்பது அதிக எண்ணிக்கையில் கழிகளைத் தோற்றுவிக்கும். முதல் ஆண்டில் மூன்று முறையும், பின்பு அடுத்த இரண்டு ஆண்டுகளுக்கு இருமுறை என்னும் களை நீக்கி மண்ணைக் கொத்திவிட வேண்டும். வறண்டுவிட்ட நாற்றுக்களை நீக்கி விட்டு, புது நாற்றுக்களை நடவேண்டும். மூங்கில் நாற்று நட்ட பிறகு சாருதலைக் மேயாமல் இருக்க வேலிபோடுவது மிக முக்கியம்.

வளர்ச்சி

நாற்று நட்ட ஒரு ஆண்டுக்குள் வேர்ப் பகுதிகள் முழுமையாக தோற்றுவிக்கப்படுகின்றன. பின்னர் வேர்ப்பகுதிகளிலிருந்து கழிகள் தோன்றத் துவங்குகிறது. பொதுவாக மழைக்காலங்களில் கழிகளின் எண்ணிக்கை அதிக அளவில் காணப்படும். இவை பின்னர் விரைவாக வளர்ந்து 90 நாட்களுக்குள் முழுமையான உயர வளர்ச்சியை அடைகின்றன. ஒரே நாளில் 30 - 40 செ.மீ. வளரக்கூடியது. முதலாவது மாதத்தில் கணுக்களில் காணப்படும் தோகைகள் கழன்று, கிளை மொட்டு தெரியத் துவங்கும். பின்னர் இவை விரைவான வளர்ச்சி அடைந்து, மூன்றாவது மாதத்திற்குள் இலை மொட்டுக்கள் கிளைகளில் தோன்றி, இலைகள் வரத் துவங்கும். இத்துடன் ஒரு மூங்கிலின் உயர வளர்ச்சி, பருமன் அளவு முழுமையாக முடிவடைந்து விடுகின்றன. பின்னர் இவற்றின் கடினத்தன்மை மில்லுட்டும் மாறுதல்கள் நிகழ்கின்றன.

பொதுவாக நடவு செய்த நாற்றுக்கள் அனைத்தும் மூங்கில் தூர் ஏற்படுத்தும். மிகச்சிறந்த முறையில் பராமரிப்பு செய்தால், நடவு செய்த ஒரு வருடத்திற்குப் பின், ஒரு ஹெக்டேரில் சராசரியாக 1250 கழிகளும் 2, 3, 4, 5 மற்றும் 6-வது ஆண்டுகளில் முறையே 2250, 3000, 3500, 4000 மற்றும் 4500 மூங்கில்களும் உற்பத்தியாகிறது என்பது ஆராய்ச்சியின் மூலம் தெரியவந்துள்ளது. மேலும் வரும் ஆண்டுகளில் தோற்றுவிக்கப்படும் மூங்கிலின் எண்ணிக்கை அதிகமாகும். முதல் ஆண்டில் மூங்கில் சராசரியாக 1.5 மீட்டர் உயரமும், 2 செ.மீ. பருமனும் கொண்டுள்ளது. படிப்படியாக வளர்ச்சியடைந்து 6-வது ஆண்டில் 28 மீட்டர் உயரமும், 8.5 செ.மீ. பருமனும் கொண்டதாக உள்ளது.

மூன்றாண்டுகளுக்கு குறைந்த வயது உடைய கழிகளை அறுவடை செய்யக்கூடாது. முதிர்ந்த கழிகள் ஒரு தூரில் 12-க்கும் மேற்பட்டு இருக்குமேயானால் குறைந்தது ஆறு கழிகளை வெட்டாமல் விட்டுவிடவேண்டும். மூன்றுக்கும் குறைவாக இருக்குமேயானால் எதையுமே வெட்டக்கூடாது. கழிகளை முதல் கணுவுக்கு மேல் ஒட்டி வெட்ட வேண்டும். இல்லையேல் கழிகளில் நீர் தேங்கி அனை அழுகி விடும். அடிக்கிழங்கை எக்காரணத்தைக் கொண்டும் தோண்டுதல் கூடாது. ஒவ்வொரு தூரிலும் சுமார் 10 முதல் 30 கழிகள் இருக்கும்.

நோய்க் கட்டுப்பாடு

மூங்கில்களில் வரும் வெக்கை நோய் அதிக கேடு விளைவிக்கக்கூடிய நோயாகும். இந்நோய் தாக்கிய பகுதிகளை நீக்கி விடவேண்டும். பின்பு பாவிஸ்டின் (0.3 சதம்), ஃபிட்டோலான் (0.4 சதம்), டைத்தேன் எம் - 45 (0.4 சதம்) போன்ற ஏதாவது ஒன்றையோ அல்லது பாவிஸ்டின் 0.5 சதத்தையும், ஃபிட்டோலான் 0.3 சதத்தையும் கலந்தோ அல்லது பாவிஸ்டின் 0.5 சதத்தையும், ஃபிபூரடான் 25 கிராமையும் கலந்து விரைத் தெளிப்பான் மூலம் தெளிக்கலாம். ஒரு தூருக்கு 3 - 4 லிட்டர் மேற்கூறிய கலவையை ஜூன் - ஜூலை மாதங்களில் தெளிக்க வேண்டும்.

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(10)

Sonak, wheat variety for late-sowing

SONALIKA, a golden bold-seeded wheat variety was dominating, in the Seventies and early Eighties, in late-sown conditions throughout India. As it was struck by rust and Karnal bunt, it had to be withdrawn. Since then, farmers of the north-western wheat belt have been clamouring for its replacement.

Now, scientists at the Chaudhary Charan Singh Haryana Agricultural University, Hisar, have come out with a replacement, Sonak, an improved wheat variety for late — and very late-sown conditions of Haryana and adjoining states. The variety has been released by the Haryana state sub committee and notified for commercial cultivation.

Sonak is an improvement on Sonalika incorporating disease- resistant genes from Lr 24 employing back cross techniques for seven generations. This line was evaluated at various wheat research centres for several years against check varieties. Its average performance during 1989- 96 under late-sown conditions was 47 quintals per hectare against 41 quintals and 40 quintals per hectare of Sonalika and HD 2285.

Under very late-sown conditions (up to mid-January), Sonak gave an average yield of 43 quintals per hectare against 38 and 39 quintals per hectare of Sonalika and HD 2285.

Under farmers' field trials in 1994-95, Sonak gave an average yield of 39 quintals per hectare against 35 quintals by Sonalika. WH 291 and HD 2285 in the first year. During 1995-96, Sonak gave an average yield of 43 quintals per hectare against 41 quintals by the check varieties.

Sonak was found to resist leaf rust, yellow rust and leaf blight while the check varieties were highly susceptible. Sonak showed field resistance to shoot fly attack also while Sonalika and other check varieties are damaged by the fly which is a menace under late-sown conditions. Sonak showed improvement in quality traits such as protein content, sedimentation value and pelshenke value. The chapati score was the same as that of Sonalika.

Sonak has the same phenotypic characters of Sonalika like plant type, growth, heading, maturity and height. Sonak is distinct with respect to leaf rust resistance and with light brown colour of the matured ears compared to the deep brown colour of Sonalika ears. Like the parent variety, Sonak is adaptable to different agro-climatic conditions.

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Zinc with FYM/coirpith boosts rice-groundnut yield

EXPLOITATIVE agriculture involving intensive cropping with high yielding varieties and use of high-analysis, micronutrient-free fertilizer such as DAP instead of superphosphate have led micronutrient deficiencies.

Importantly, zinc has become the most limiting element in the soil. In Tamil Nadu, 52 per cent of the soil exhibit zinc deficiency. The deficiency is more in intensively cultivated agricultural zones.

Rice fields are prone to zinc deficiency. It also is commonly seen in sugarcane, groundnut and pulses.

It is also amended by applying of zinc sulphate, mainly for cereals, oilseeds and pulses, at the rate of 25 kg/ha.

Through various soil reactions zinc applied gets converted into unavailable forms. Its use efficiency is reported to be 1-2 per cent only.

Eventhough the synthetic chelates are useful in supplying more zinc to the plants, the high cost is a limitation.

Hence integrated plant nutrition involving judicious use of organics and inorganics is gaining momentum.

Improved nutrient availability by the application of oraganics may be attributed to formation of organically complexed zinc besides creating conducive soil environment and favourable influence on physical, chemical and biological properties of the soil.

Also, an array of organic acids released by the decomposition of organic matter in the soil solubilise the zinc.

Therefore an attempt was made to improve zinc use by the crop as will reduce the fertilizer required and help maintain the soil health.

Blending zinc sulphate with organic manures and incubating for a considerable period will help provide a suitable environment for the formation of zinc complexed/chelated compounds.

Availability of zinc and period of availability will be more compared to the inorganic zinc sulphate.

Investigations were undertaken to evaluate the usefulness of zinc-enriched organic manures.

They were prepared by mixing 750 kg of FYM/raw coirpith with 12.5 kg zinc sulphate $7H_2O$, maintaining sufficient moisture (to feel wet) and incubated for 30 days.

Field experiments were conducted in a zinc-deficient soil. The direct effect was seen in the first crop of rice (ASD/18), while the residual effect was evaluated in a succeeding crop of groundnut (Co1).

The rice yield was increased by 4.75, 6.20 and 7.25 q/ha with 25 kg zinc sulphate/ha, zinc-enriched FYM and coirpith with 12.5 kg zinc sulphate respectively.

Residual effect was seen as pod yield of groundnut — the ranking was zinc — enriched coirpith zinc-enriched FYM zinc sulphate.

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Tips to grow bamboo

BAMBOOS are normally found in forest areas throughout Asia and the Pacific. Although a major part of the requirement for bamboo is presently being met from natural stands, the increasing demand for housing and construction can be provided for in the future only from the extended plantations on marginal soils (Coxi and Utisols).

Extensive plantations of bamboos, mostly *Bambusa bamboo* have recently been grown in several regions of India to meet the increasing demand for long — fibre pulping material.

Bamboo, which are giant, woody, tree-like grasses, have a long history as an exceptionally versatile and widely used resource. Under suitable conditions this crop displays prodigious rates of growth. Some species can produce culms 40 m high and 30 cm in diameter in just four months.

Bamboo displays fast rates of growth. Some species can produce culms 40 m tall and 30 cm in dia in 4 months.

The total length of culms produced by a giant bamboo clump over its life time can well exceed 15 km. It has two kinds of flowering behaviour: first, a sporadic and irregular flowering and second, periodical gregarious flowering.

The gregarious flowering is followed by death of the clump and varies from 20 to 75 years depending upon the locality, management practices and biotic interferences.

A complete bamboo plant consists of three morphologic structures, the leafy aerial part (the culm) and underground parts (rhizome and roots). For successful growth all these structures must develop.

Failure in any of these phases leads to a complete failure. Most bamboo species of commercial importance form clumps (a cluster of culms). The new seedlings (the seedlings resembles a blade of grass) produces a rhizome, which develop new rhizomes that produce culms.

The number of new rhizomes may vary from one to many. Depending upon the production of rhizomes, bamboos are classified into three types.

— Monopodial — the rhizome having one bud at each node which develops monopodially every year.

— Sympodial — the apex of the rhizome having nodes but no buds does as the monopodial type and protruding out of the ground and growing into a culm.

— Intermediate — intermediate between monopodial and sympodial.

Over-exploitation associated with a growing human population, destruction of tropical forests and new demands on this resource for industrial uses, especially by the pulp and paper industry, has resulted in wide-scale decimation of bamboo stocks.

From vast forests of bamboo in the south and southeast Asia at the beginning of this century, we are now left with a situation of scarcity.

Many countries have been forced to severely restrict harvesting and exporting of bamboos. The availability of bamboo can be sustained only by raising bamboo plantations.

As bamboo seeds possess a short period of viability (a few days to 1 month), Seedlings from tissue culture were employed. A nursery area of 10x5m was prepared in the field and filled with a mixture of soil and sand (3:1).

The seedlings were pricked out from polythene bags when about 7cm tall. About 25 seedlings were planted in 1 square metre of a raised nursery bed. Watering was done 2-3 times a day and care taken to avoid oversaturation.

Nursery beds were provided with a thatch to protect the seedlings from direct sunlight.

Transplanting

The seedlings were uprooted carefully and transplanted at an espacement of 6m with 250 seedlings per ha. The transplanted seedlings were watered every 2 hours regularly.

Weeding was done as and when required. After 1 year, the plantation was adequately irrigated at 15 day intervals.

Care was taken to avoid water logging. The plantation was protected against damage by rodents and grazing.

Growth and production of culms.

All the transplanted seedlings produced rhizomes. The culm buds emerge with the onset of early rains and grow rapidly. They reach full height within 90 days.

An unusual rain during winter may induce emergence of new culms, but they do not grow successfully like those produced in rainy season. The culms are very tender during the growing period.

It has been observed that the daily growth of a culm is approximately 33 cm. The internodes are wrapped with sheaths. In the first month the culms lose their sheath and develop shoot buds.

These start to elongate during the second month. The maximum length of side shoots is 150 cm. In the third month, side shoots develop leaves. Then the culms continue to change density. After this they start changing colour.

The new culms formed along the outside edge of the clump tend to grow inwards and get entangled among the older culms.

Management

Seedlings obtained from tissue culture methods should be used. Polythene bags (20cm x 30cm) were filled with clean soil, sand and manure in the ratio 2:1:1. About 15 plants were planted in each polythene bag.

Watering should be done 2-3 times a day and care taken to avoid oversaturation. Seedlings were kept in the bags for one month. The nursery should be raised in shade.

In each polythene bag, the number of rhizomes may be 4 to 5. These rhizomes are not singled out or sorted, but the entire thing should be planted in pits of size 45cm x 45cm x 45cm at a spacing of 6 m x 6 m. (One week prior to planting, the pits were treated with 0.01 per cent aldrex and 0.05 per cent bavistin to prevent termite and fungal attack.

Planting should be completed before the monsoon fully sets. To provide better initial growth environment to the seedlings, the upper half of the pit should be filled with a mixture of 2 kg gram vijay complex, 17:17:17 per pit and the lower half with the original soil.

The transplanted seedlings produce rhizomes which develop new rhizomes and lateral culms. At a given site, the production of new culms depends on the culms of the previous year, degree of congestion and clump age.

The average annual recruitment of culm generally increase year after year. The culms produced during the first year is shorter in length and smaller in diameter, but culms from subsequent years will be longer and bigger.

Rhizome development is not peripheral as generally believed. Rhizomes may develop in any direction and the culms may appear anywhere in the clump provided overhead light is available for the emergence of the culm.

It is only in congested clumps that new culms appear to grow at the periphery. The new culms can even be seen in the middle of the clump.

New culms are produced each year. Older culms should therefore be harvested every year. Culms older than two years take little part in the growth of new culms. Retention of culms older than two years is therefore not needed. Culms older than three years are fully mature for the desired end use.

Where congestion has already set in, the culms should be removed even if it leaves only the current-year culms. Where young culms are twisted from the top, they should be cut to allow new culms grow freely.

Felling should not be carried out from July to October. Mounding (or) heaping earth around the bamboo culms should be carried out after every felling. Bamboo clump should in no case be cleared. If cleared, the clump generally degenerates into a bush.

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தினமணி
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புதன்கிழமை தோறும் படியுங்கள்
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10 திங்கள்கிழமை, 9 நவம்பர், 1998

நூற்புழு இல்லையேல்

நூற்புழுக்கள் கண்ணுக்குத் தெரியாத, மண்ணில் வாழும் உயிரினமாகும். இவை முதலில் வேரில் மேல் பாகங்களில் காயங்களை ஏற்படுத்துகின்றன. பின்பு, அதனுள் இருந்து கொண்டு, சாற்றினை உறிஞ்சி பயிருக்கு அதிக சேதத்தை விளைவிக்கின்றன. அது மட்டுமல்லாது, காயம்பட்ட பகுதியில் வழியே, நோய் ஏற்படுத்தும் பூஞ்சாண மற்றும் பாக்டீரியாக்கள் உள்ளே நுழைந்து, பயிருக்கு நோய்களை உண்டுபண்ணுகின்றன.

தற்போது, திருநெல்வேலி மாவட்டத்தில் தக்காளி, வெங்காயம், வெண்டை, மிளகாய் போன்ற காய்கறி பயிர் சாகுபடி நடைபெறுகிறது. இப் பயிர்களில் இந்நோய்த் தாக்குதலைக் கண்டறிந்து தவிர்க்கமுடியும்.

அறிகுறிகள்: வேர்களில் சிறிதும் பெரிதுமான வெட்டுமுச்சுக்கள் காணப்படும். (கடலைச் செடியில் காணப்படுவதுபோல் இருக்கும்). தாக்கப்பட்ட வேர்கள் நாளடைவில் அழுகி, செடிகள் காய்ந்து விடும். தாக்கப்பட்ட செடி வளர்ச்சி குன்றியும், இலைகள், வெளிர் பூஞ்சள் நிறமாகியும், வளர்ச்சியடையாமல் சிறுத்தும் இடைக் கணுப் பகுதிகள் குட்டையாகவும் காணப்படும்.

வேர்ப்புழுக்கள் அதிகமாக இருக்கும் இடங்களில் வீசுகள் முளைக்காது. முளைத்த இளம் செடிகளும் காய்ந்துவிடும். இதனால் மண்வளம் குறைந்த திவுக்கில் சாகுபடி செய்த பயிர்களைப் போல வளம் குன்றியதாகவும், தழைச்சத்து, சாம்பல்சத்து மற்றும் நுண்ணூட்டச்சத்து, பற்றாக்குறைக்காக அறிகுறிகள் போல பச்சையம் இன்றி வெளிறிக் காணப்படும்.

வேரில் திசுக்கள் தாக்கப்படுவதால், உணவு மற்றும் நீர் செடிகளுக்குக் கடத்தப்படுவது குறைவதோடு, வேர் அழுகி, பிறகு இறந்துவிடுகிறது. மகசூல் 25 சதவீதம் குறைந்துவிடும்.

கட்டுப்படுத்தும் முறை: கோடை உழவு செய்ய வேண்டும். இதனால் குளிர வெப்பத்தால் புழுக்கள் இறந்துவிடும். துளுக்கர் சாமந்தி, எள், சணப்பு போன்ற பயிர்களை ஊடுபயிராகவோ அல்லது மாற்றுப் பயிராகவோ வரப்பு ஓரங்களில் நடுவதன் மூலம் நூற்புழுக்களின் இனப்பெருக்கம் பாதிக்கப்பட்டு, அழிக்கப் படுகின்றன. உதாரணமாக, மியூரான் 3 சதக் குறுவை மருந்தினை 1 சதுர மீட்டருக்கு 15 கிராம் என்ற அளவில் 15 நாள் களுக்கு முன்பே இட வேண்டும். நூற்புழுக்களின் தாக்குதல் வயலில் காணப்பட்டால், கார் போபியூரான் 3 சதக் குருணை மருந்தினை, ஒரு செடிக்கு ஒன்றரை கிராமிலிருந்து 2 கிராம் என்ற அளவில் இட்டு, நீர் பாய்ச்ச வேண்டும்.

பி.ஆர். பிரேமேந்த சந்திரன்,
திருவண்ணமாளிகாபுரம்,
ஆய்க்குடி, திருநெல்வேலி.

குண்டு குண்டு தக்காளி

தக்காளி நாற்றுகளை நடவு செய்யும் முன்பு, நிலத்தை நன்கு உழுது, 15 நாள்கள் ஆறவிட வேண்டும். பின்பு, 10 டன் தொழுவுரம் அல்லது மக்கிய குப்பை, 50 கிலோ தழை, 50 கிலோ மணிச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை அடியுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 15 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்தை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 30 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 45 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 60 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 75 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 90 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 105 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 120 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 135 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 150 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 165 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 180 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 195 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 210 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 225 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 240 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 255 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 270 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 285 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 300 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 315 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 330 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 345 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 360 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 375 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 390 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 405 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 420 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 435 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 450 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 465 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 480 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 495 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 510 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 525 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 540 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 555 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 570 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 585 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 600 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 615 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 630 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 645 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 660 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 675 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 690 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 705 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 720 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 735 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 750 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 765 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 780 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 795 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 810 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 825 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 840 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 855 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 870 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 885 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 900 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 915 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 930 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 945 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 960 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 975 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 990 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1005 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1020 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1035 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1050 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1065 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1080 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1095 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1110 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1125 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1140 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1155 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1170 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1185 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1200 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1215 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1230 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1245 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1260 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1275 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1290 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1305 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1320 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1335 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1350 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1365 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1380 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

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நாற்றுகளை நடவு செய்த 1410 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1425 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவு செய்த 1440 நாள்களில் ஒரு ஹெக்டேருக்கு 50 கிலோ தழைச்சத்து, 50 கிலோ சாம்பல் சத்து மற்றும் 25 கிலோ நுண்ணூட்டச் சத்து கலவை ஆகியவற்றை மேலுரமாக இட வேண்டும்.

நாற்றுகளை நடவ

Nature's Tall Stalks

Grass Bamboos, with their remarkable biology, make a fascinating subject of research

BY DR. P. SHANMUGHAVEL & DR. K. FRANCIS

BAMBOO belongs to a unique group of giant arborescent grass, in which woody culms (a jointed stem that is usually hollow) arise from underground rhizome (a horizontally creeping underground stem) appearing like a shrub or a tree-like habit. Their culms are erect, sometimes climbing. Bamboos are characterised by woody, mostly hollow, culms with internodes and branches at the culm nodes. They are part of the grass subfamily *Bambusoidae*, a tribe under the *Gramineae*.

The name bamboo was introduced by Linne in 1778 from the word 'Bambu' or 'Mambu'. To layman, all bamboos look alike but there are more than 1,250 species described under 75 genera. India has perhaps the world's richest resources of bamboos, having about 130 species occurring over an area of 10.03 million hectare which is about 12.8 of the total forest area of the country. The biology of bamboos is remarkable and peculiar from several points of view.

Clumps of bamboo

Bamboo forms a rich belt of vegetation in moist deciduous, semi-evergreen, tropical subtropical and temperate forests. Climatically, bamboo prefers regions of high rainfall ranging from about 1,270mm to about 6,350mm or even more, though they also occur in dry deciduous forests with as low a rainfall as 750mm

A maximum temperature of 46.7°C and a minimum of 3.3°C are recorded from bamboo-bearing areas.

A complete bamboo plant consists of three morphologic structures - the leafy aerial part (the culm) and two underground parts (the rhizome and roots). For successful growth, all these structures must develop. Lack of development of any of these phases leads to complete failure.

Most bamboo species of commercial importance produce clumps (a cluster of culms). The new seedling (seedling resembles a blade of grass) produces rhizome, which develop new ones that produce culms. Depending on the production of rhizomes, bamboos are classified into monopodial, sympodial and intermediate type.

Monopodial: The rhizome which has one bud at each node develops monopodially every year. Eg. *Phyllostachys reticulata*.

2. Sympodial: The apex of the rhizome, which has nodes but no buds as such in monopodial types, at them protrudes out of the ground and grown into a culm. In the following year, the bud on the basal part of the culms develops into a short rhizome, which protrudes out of the ground to make secondary culm thus forming a clump, Eg. *Bambusa Bambos*.

3. Intermediate: In between the above two types Eg. *Sasa paniculata*.

A culm bud emerging out of the soil

Growth: Two kinds of buds are observed on the rhizomes - the scaly pointed buds and the flat ones. The former develops into rhizome and the latter into culms. The scaly buds are formed during summer, while the culms buds develop during winter. The culm buds emerge out of the soil with the onset of early rains and grow rapidly. They reach full height within 90 days. The culm are very tender during the growing period. It has been observed that the daily height growth of culm is approximately 33 cm. Height growth is caused by the successive elongation of the internodes. The basal internode is the first to grow and the top most one is the last. The internodes are most carefully wrapped up on sheaths. In the first month, culms lose their sheath and develop side shoot buds. These buds begin to elongate during the second month. The maximum length of side shoot is up to 150cm. In the third month, side shoots develop leaves, then the culm continue to change in density. The new culm formed along the outside edge of the clumps often tend to grow inwards and to get entangled among the older ones. They grow tough during the second year and mature during the third.

A young bamboo seedling

Seedlings of bamboo produced only a three full-grown culms per clump in the first year after plantation. The number of full-grown culm gradually increased in the subsequent years up to six years and found decreased. It was noticed that culms emerged in the first year were short (1.4m) and smaller (2.3 cm) in diameter at breast height. Culms produced in the subsequent years were distinctly taller and bigger in diameter. Culms were produced until it flowers. Once flowered, the life cycle of bamboo will be over.

However, bamboo differ significantly from other vegetation because of the mechanism of flowering. Most of the woody bamboo flower and seed after on exclusive vegetative growth for a species specific supra annual interval, ranging between 3 and 120 years. Due to this peculiar habit of flowering behaviour in bamboo, seeds were available only at very long intervals. So plantations were raised only using the tissue cultured plants.

(The authors are from the Bharathiar University, Coimbatore)

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"In the 1970s, we got our first taste of what it was like when the fuel begins to go away," Tao says. "Three decades later we're beginning to see the start of another large petroleum crunch. And part of that is consumer demand, which has greatly increased. Consumers like this stuff."

Anyone standing at a gasoline pump watching the digits scroll by may wonder whether prices are going to go down. Over the long-term, Tao points out, they won't.

"One-time-use resources, which are also known as non-renewable resources, such as petroleum, are a problem because you eventually run out," he says. "Eventually we will have to switch from using non-renewable resources to using renewable resources."

But Tao and others say that the potential is already there for common field crops, such as corn and soybeans, to replace petroleum oil as the driver of the economy within a few decades.

petroleum are plant oils and fats because they have the same base chemical structure as petroleum," he says.

Ethanol is a type of alcohol made by fermenting plant material. Although it makes a good fuel, it has drawbacks, Tao says. "The economics of ethanol production are improving as the technology improves," he says. "But ethanol has two problems: It doesn't explode like gasoline, and it can absorb water, which can cause oxidation, rust and corrosion."

By manipulating plant oils, Tao says it may be possible to create a petroleum substitute.

Fossil fuels were plants once, millions of years ago, and so it makes sense that both the fossil fuels we use today and oils produced by plants are chemically similar. Both are made up of chains of chemicals known as hydrocarbons.

A hydrocarbon is a carbon atom surrounded by hydrogen atoms. Methane, the

10 hydrocarbons long. "In fact, the word 'octane' means eight carbons in a chain," Tao says.

The shorter the chain of carbons, the more explosive the fuel is, and the more power it offers an engine.

The problem is that plant oils are 14 to 18 carbons in length. "Diesel fuel is 15 carbons long, which is close to the same size as plant oils. That is why the first applications are as biodiesel fuel," Tao says. "You couldn't burn vegetable oils in today's gasoline engines because their hydrocarbon chains

Tomorrow's Oil Barrels!

"Not surprisingly, shorter, chain vegetable oils do exist," he says. "Coconut oil, tropical oils and similar plant oils might make a reasonable gasoline-like fuel. It might also be possible to transgenetically modify crops to produce plants with those lengths of fatty acids."

Tao says future scientists could genetically modify corn and soybeans — which are already two of the highest oil-yielding plants — to produce plant oils that could be converted into a type of gasoline.

is used, the largest number of applications is in inks, paints and coatings."

Chemists have known for decades how to alter the hydrocarbon chains in petroleum through processes known as cracking and reforming. Shortened hydrocarbon chains are used as solvent bases for paints and chemicals. Longer chains — as many as 200 hydrocarbons — are known as plastics. But these products also can be made from plants.

According to Tao, before World War II, most paints, coatings and adhesives were made from vegetable oils or other plant products. "In the very near future, some of these products will go back to using vegetable oils instead of petroleum," Tao says. "There are latex paints that will be appearing on the market very soon."

This isn't a new idea: Henry Ford famously made everything from clothing to automobile bumpers from vegetable oils

samples of products that were once made from plants that are now made from petroleum products. "Candles, for one," he says, holding up a blueberry-scented candle made from soybean oil. "It's only been in the last 60 to 70 years that paraffin wax candles were common."

As part of an annual contest sponsored by the Indiana Soybean Board, students at Purdue have created a variety of products that replace petroleum products with soybean oil, such as candles, crayons, ski wax and fire starters.

"There isn't a huge demand for scientists to develop soybean oil birthday candles or crayons," he admits. "But these products are safe for the students to work with. And once they know how to work with the plant oils, they we'll be better positioned to help create other new products over the next 40 years.

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The Tale Of Bamboo

By Dr P. Shanmughavel & Dr K. Francis

THERE are more than 1,250 species of bamboo under 75 genera. India is perhaps the world's richest resource of bamboo. It has about 130 species occurring over an area of 10.03 million ha, this is about 12.8 per cent of the total forest area of the country and represent 30 per cent at India's total production.

Bamboo forms a rich belt in moist deciduous, semi-evergreen, tropical, sub-tropical and temperate forests. Genus *Bambusa* is widely distributed in India. *Bambusa bamboo* occurs either wild or cultivated in the plains and low hills of India.

The other widely distributed genus is *Dendrocalamus*. It occurs in the plains of south, central India, dry hills of north India, Punjab, Assam and other North-Eastern states. Genera *Bambusa*, *Oxytenanthera* and *Dinochloa* are widely present in the Andamans and Nicober islands. Other principal genera of India like *Arundinaria*, *Indocalamus*, *Oxytenanthera*, *Schizostchyum* and *Melocanna* are concentrated in the Western Ghats.

Growth Characteristics

Development of Bud: The bamboo forms a unique group of giant arborescent grass. Bamboo grows in two distinctly different forms due to the types of its subterranean rhizome., i.e., either single stemmed, monopodial (Leptomorph), or densely clumped, Symbodial (Pachymorph).

A complete bamboo plant consists of three morphologic structures - the leafy aerial part called culm and two underground parts, rhizome and roots.

The stems are called culms and their joints nodes. A scaly rhizome or underground stem is produced from the base of

Origin of a flat rhizome

the seedling-plant which after growing vertically downwards for a short distance, curves up again and appears as a small culm (bud).

Initially, the buds in a rhizome are flat, less than 2.5 cm in diameter and are covered profusely with scales. The scales, which are not apparent, develop as the buds grow. Scales are underdeveloped sheaths of the future culm. Just before the onset of monsoon, the buds begun to grow. They appear above ground during the monsoon.

Before the culm appears above the ground, the new growth develops into a complete rhizome to support the culm. The function of the rhizome is to give support to the growing aerial shoots (culms) and to act as a feeding channel. The feeding organs of a rhizome are the slender rootlets which are capable of going from a few centimetres to a metre deep underground.

The sheaths are of vital importance to culms during growth. Each internode is carefully wrapped in a single sheath. The basal internode always has more than one sheath. In a bud, the sheaths are arranged alternately clockwise and anticlockwise. The sheath is a nurse to the tender internodes against injury and desiccation. Its outer surface is armed with a cluster of stiff hairs, which are detached on the slightest touch and cause irritation to any naked part of the human body.

A bud is a complete miniature bamboo with a rhizome and culms. Similarly, a culm above ground is a complete aerial shoot irrespective of its size. There is no terminal growth. The height growth of the culm is caused by the successive elongation of the internodes.

Internodes wrapped in a single sheath

Completion of elongation of internode takes place within a few days, say about 15 days. More than one internode grows at a time, but the number of such internodes growing simultaneously is limited to about 5 to 8. In the early stages, the height growth of a culm is slow, about 10 to 15 cm per day. After the culm has reached about 3 meters in height they start shooting very fast.

In bamboos, even a large culm of 35 metres height attains its full height in 2-4 months. Then the culm tissues harden the internodes become hollow and branches with leaves are formed in the upper part. In some species like the Giant Bamboo, the sheath covered shoots emerge from the soil at the rate of four cms per hour. So rapid is the growth on moist, warm mornings that we can actually hear the shoots grow.

Clump and Culms

Most bamboo species of commercial importance form clumps. The new seedling produces rhizomes that in turn produce culms. New rhizomes develop from the previous rhizomes. In India, new culms generally appear during the rainy season.

Two kinds of buds are observed on the rhizomes, scaly pointed and flat buds. The former develop into rhizomes and the latter into culms. The scaly buds are formed during the summer months while the culm buds develop during winter.

Culms are tender during the growing period. They grow tough in the second year and are mature in the third year. At the age of three years they acquire full

A single clump

density and strength. After this age they start changing colour.

Rhizomes

Rhizomes generally grow at an upward inclined angle. The angle of incline depends on the species and the condition of soil. During this period of growth any exposure to sunlight stops the rhizome development. Rhizomes may develop in any direction and the culms may appear anywhere in the clump.

Flowering

Most of the woody bamboos flower and seed after an exclusive vegetative growth for a species specific supra annual interval, ranging between 3 and 120 years. There are three types of flowering. Those which flower gregariously and periodically; (ii) those which flower irregularly; (iii) those which flower annually. In gregarious flowering, all members of a cohort (plants from seeds of common origin) enter the reproductive phase approximately at the same time and after flowering and seeding the parents die enmasse. This death of the bamboo parents used to be given more importance, probably because of their long intermast periods and arborescent habits.

In sporadic flowering, members of a cohort enter the reproductive phase at different or irregular intervals and after flowering (and seeding) the parents do not die but revert to vegetative growth.

Some species like *Indocalamus wightianus*, *Bambusa arra* and *Oclandra scriptoria* flower annually.

This peculiar flowering behaviour in bamboos has resulted in a poor understanding of their inter-relationships, besides making the perennial raising of plantations using seeds and hybridizations difficult.

The National Chemical Laboratory (NCL), Pune has developed a technique for simultaneous flowering and hybridisation of different species.

The team used the tissue culture technique in which the growing regions, such as the shoot tips, are used to obtain a large number of plantlets in the case of species which are rare or flower at long intervals.

The research carried out in this field lays the foundation for the exploitation of the tremendous genetic variation available in bamboo.

(The authors are from the Dept of Botany, Bharathiar University, Coimbatore)

Database Model For Industrial Plantations

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Abstract: This paper discusses the computer-aided database for industrial plantations. The computer-aided database is developed for quick reference to Research Scientists, Scholars, Pulp and Paper industries and Forest officials involved in cultivation and Management of Forest Plantations. This work aims at maintaining the techniques and concepts in Tracking Forest Plantation details in a more simpler and effective way using Visual Basic 6.0 as the Front end tool and Oracle 8.0 as the Back end tool. It also maintains a catalog of important forest plantations in a more efficient and consistent manner and tracks the growth, nutrient analysis, pulps and papers characteristics.

Keywords: Database, industrial plantations, *Bambusa bambos, Eucalyptus tereticornis, Acacia decurrens, Acacia arabica, Erythrina suberosa, Dondrocalamus hamiltonii, Acacia holosericea, Prosopis cineraria, Acacia catechu, Shorea robusta*

Introduction

In Forestry and related disciplines, it is widely recognized that rapid, reliable and universal access to quality information is essential for informed decision making concerning plantation forests and all their inherent values. Nowadays, plantation are raised by the forest department under various forestry programs. Work done in India and elsewhere and growth and productivity of forest plantations is very meager. The importance of physical properties of soil for tree growth has been taken into consideration while selecting the tree species. Further, there are known sources of variations, which need to be considered in relation to the availability of the nutrients. Hence, the data on nutrient distribution in biomass components of various trees (*Bambusa bambos, Eucalyptus tereticornis, Acacia decurrens, Acacia arabica, Erythrina suberosa, Dondrocalamus hamiltonii, Acacia holosericea, Prosopis cineraria, Acacia catechu, Shorea robusta*) is included in our system.

However, no system is developed so far, for the benefit of forest officials, scientists, Pulp and paper industries. Hence, the proposed model deals with the edaphic factors that needs for raising a particular plantation crop, its growth, nutrient content, pulp and paper characters etc. If forest officials or paper industries wishes to raise a plantation, they can use this model as quick reference sources. The data will be presented in an efficient database that gives reliability and consistency of data.

The client / server application architecture was introduced to addresses issues of cost and performance. It allowed applications to run on both the workstation and the server. In this architecture, two separate applications independently could work together to complete a task. A well known implementation of this concept is SQL based Data Base Management System (DBMS). Client / Server refer to a process involving two independent entities – a client and the other a server. The client makes the request to the server and the server services the request. The proposed model in this study is based on this concept.

System Overview

Objective of the System

To develop Quick reference materials to Research Scientists, Scholars, Pulp/Paper Industries and Forest officials involved in Cultivation and Management of Forest Plantations.

To Maintain Bio Information Techniques and Concepts in Tracking Forest Plantation Details in a more simpler and effective way using Visual Basic 6.0 as the Front End Tool and Oracle 8.0 as the Back End Tool.

This project also tries to maintain a catalog of important forest plantations in a more efficient and consistent manner and tracks growth, soil, nutrient analysis and pulp and paper characteristics.

2. Existing System Overview

No model is available for quick reference to research scholar scientists, forest officials, pulp and paper industries. They search for libraries and web site for getting information. This is a time consuming task. To facilitate them these systems are attempted.

3. Proposed System Overview

The proposed model deals with the edaphic factors that is needed for a particular plantation crop, its growth, nutrient content, pulp and paper characters etc. If forest official or paper industries wants to raise a plantation, they can use this system as a quick reference source. The data will be presented in an efficient database that gives reliability and consistency of data.

4. Features of the Proposed System Overview

- Low cost and easy maintenance
- Simpler user Interface
- Consistency with the database
- Data is presented in an efficient database that gives reliability and consistency of data.
- File server architecture allows adding and reducing computer resources as needed.
- Transaction happens successfully and therefore no change of incomplete transaction.

5. Hardware And Software Specifications System Requirements

This system is developed on Microsoft Windows NT 4.0 Operating System compatible with Win9X. It is highly user friendly. Lot of Front End Tools and Back End Tools are available in the market. Still this system has been developed on the famous and powerful Front End Tool viz. Microsoft Visual Studio 6.0 Enterprise Edition and the powerful and reliable Oracle 8.0 as the Back End Tool.

Hardware Requirement

Processor	Intel Pentium and above
RAM	32 MB and above
Hard Disk Capacity	4GB and above
Monitor	15 ' Digital Color
Floppy Disk Drive	1.44 MB
Pointing Device	Serial or PS/2 is recommended

Software Requirement

Operating System	Win 9X, Win NT (with SP4)
Front End Tool	Visual Basic 6.0 Enterprise Edition
Back End Tool	Oracle 8.0 and above

Introduction To Front End

Visual Basic 6.0 is the latest version released by Microsoft and it has all the features of working with the Internet. The applications that are created using visual basic 6.0 are very easy to create and so user friendly that even a layman can also have better idea about the utility appreciated by the software professionals. Visual Basic serves as very user friendly front end, which has many fantastic features and many wizards in it, which supports both the client server utility and the Internet based utilities.

The Visual Basic enterprise edition is the most advanced edition and is aimed at programmers who build distributed applications in a team environment. The changes in the data access area and the move towards ADO. VB 6.0 has been enhanced in many other ways and VB 6.0 brings changes to the core of its development environment, the language itself.

In a Client / Server system there will be two different entities. A server that serves the request and a client that makes the request.

Two tier Client / Server architecture revolves around a desktop machine operating as a client, Network server housing the back end Database engine. Logic is split between these two locations, the client and the server. In a two tier model, the front end piece is commonly being development in Power Builders, Developer 2000, Visual Basic or some other 4 GL. The key point to remember is that, in a two-tier model business logic for the application must physically reside on the client or

be implemented on the back end within the DBMS in the form of triggers and stored procedures.

Introduction to Backend

Oracle is the most widely used database management system which is employed for Client/Server computing. The release 8 is based on the relation model and object oriented concepts and features known as ORDBMS (Object Relational Database Management System). It allows sharing of data by multiple users (or) applications (Clients / Front end) by allowing them to concurrently access a centrally maintained database server (Server/backend). At the same time it protects the database from unauthorized users by implementing various security measures. It runs virtually on every kind of computer. Still, it functions identically in all these machines. This fact makes our applications more portable.

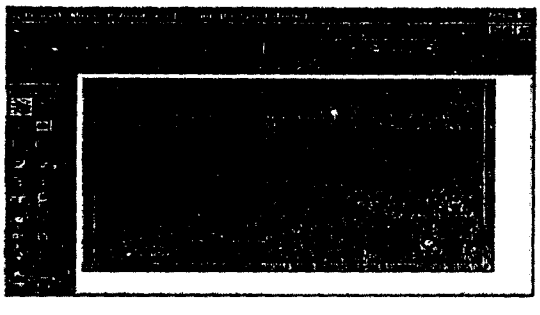
Oracle can early be used even by an end user with little or no knowledge about data processing. With Oracle an average person can be brought from beginner to an expert in short order. By using simple English like language constructs (SQL), users can extract information themselves. Technically speaking, SQL is a data sub language. It interfaces with a relational database, such as Oracle, and all SQL statements and instructions to the database. In this it differs from general purpose programming language like C and Basic.

Database Design

Table Design

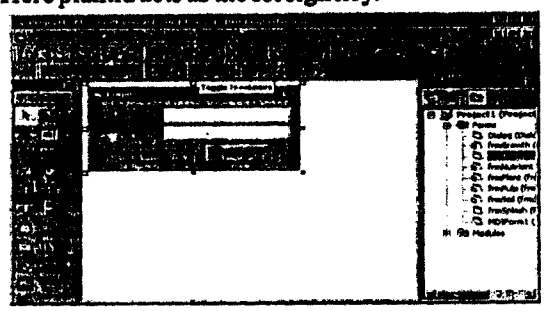
1. Plant

This table acts as a catalog for storing all plantation details. New Plantations are added to this table. Existing Plantation Details if required can be modified. This table has 5 columns namely Plant Id which acts the primary key (allows no duplication), plantation's common name and technical name with plant type and plant description.



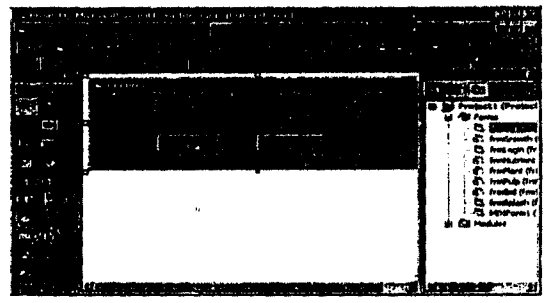
2. Growth

This table acts as reference material to any research scholar to refer the Growth characteristics of any plantation with respect to age. This table has 13 columns namely PlantId, Plantcname, Plantbname, age Basalarea, Dbh, Height, Leafbiomass, Branchbiomass, Culmbiomass Tagbiomass, Rhizome and Grandtotalbiomass. Here plantid acts as the foreign key.



3. Soil Analysis

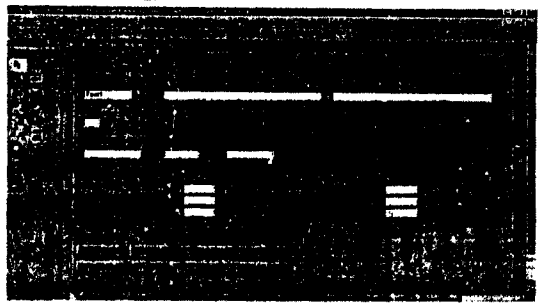
This table acts as reference material to any research scholar to refer the physical and chemical characteristics of Soil for any plantation. This table has 11 columns namely plantid, csand, fsand, silt, clay, orgcarbon, totn, availp, availk, ph, ecoп. Here plantid acts as the foreign key.



4. Nutrients

This table acts as reference material to any research scholar to refer the nutrient content and distribution in the soil for any plantation. This table contains 22 columns namely PLANTID, AGE, BLEAF_N, BLEAF_P, BLEAF_K, BLEAF_CA, BLEAF_MG, BBRANCH_N, BBRANCH_P, BBRANCH_K, BBRANCH_CA, BBRANCH_MG,BCULM_N, BCULM_P,

BCULM_K, BCULM_CA, BCULM_MG, BRHIZOME_N, BRHIZOME_P, BRHIZOME_K, BRHIZOME_CA, BRHIZOME_MG



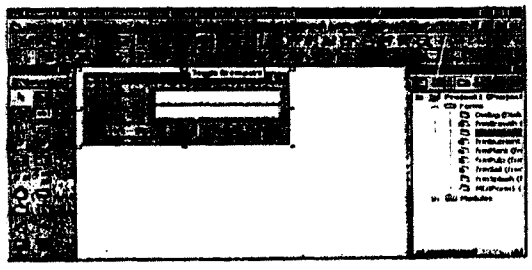
5. PAP

This table acts as reference material to any research scholar to refer the pulp and paper characteristics for any plantation. This table contains 16 columns namely PLANTID, TPY, KAPPA, ASH, CWS, HWS, ABS, SHS, PENTOSANS, LIGNIN, CELLULOSE, MOISTURE, BF, TF, BL and DF.

6. Testing And Implementation System Testing

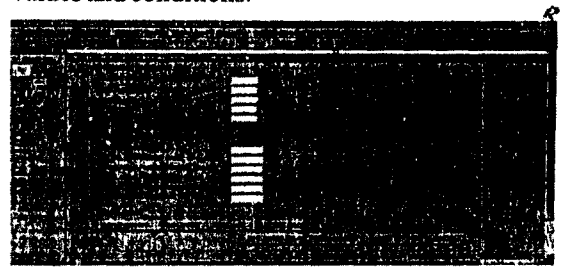
Once a project is been designed and coded, the next stage is to turn the design and coding into working system by combining all the modules and then to monitor the operation of the system to ensure that it continues to work effectively.

System testing is the stage of implementation, which is aimed at ensuring that the system works accurately and efficiently before live operation commences. In principle, system proving is an on going activity throughout the project.



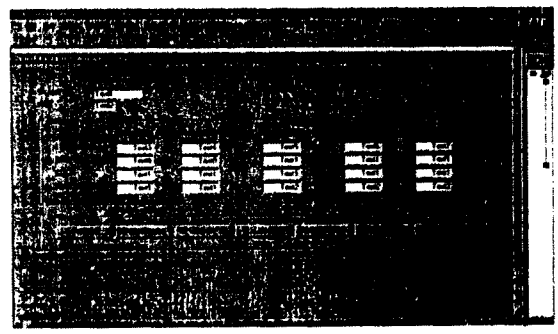
Code Testing:

This examines the logic of the program. Every path through the program is tested by using this technique. It was tested that all the individual logical paths were executed at least once. All the logical decisions were tested on both their true and false sides. All loops were tested with data in between the ranges and especially at the boundary values and conditions.



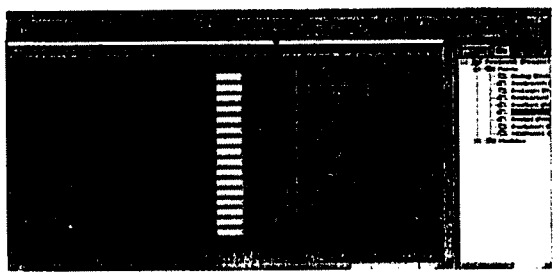
System Implementation:

Implementation is the stage of the project when the theoretical design is turned into a working system. At this stage the main workload and the major impact is on the user department. If the implementation stage is not carefully planned and controlled, it can cause chaos. Thus it can be considered as the most critical stage, in achieving a successful system and in giving the user confidence that the new system will work and be effective. Implementation involves careful planning, investigation of the current system and its constraints on implementation, design of methods to achieve the changeover, training of staff in the changeover procedures and evaluation of the changeover methods.



The first task is implementation i.e., deciding on the method and time scale to be adapted. Once the planning has been completed the major effort in the computer department is to ensure that program in the system is working properly. At the same time the user department must concentrate on training

user staff. When the staff has been trained, a full system can be carried out involving both the computer and the clerical procedures.



Specification Testing:

The system analyst, who examined the specification stating that what the program should perform under various conditions and did this testing. The test case was developed for each condition and submitted to processing. The analyst confirmed that the program performs according to its specific requirement.

Black Box Testing:

By use of this technique the missing functions were identified and placed in their positions. The error in the interfaces are identified and corrected. This technique was used to identify the initialization and termination error and correct them.

Test case are input data which are created to demonstrate both components and the total system that would satisfy all design requirements in order to make the testing process more efficient such that cases were created rather than using live data.

Acceptance Testing:

This was the last phase in the system testing process. The system was tested to check if it conformed to the customer requirements. During this stage, the system was supplied with real-time data rather than the simulated data. After the testing process was over, the system was found to work as expected. The outputs obtained from the system were in accordance to the predicted outputs.

Glossary

PLANTID	-	Plant Identification
PLANTCNAME	-	Plant Common Name
PLANTBNAME	-	Plant Botanical Name
PLANTDESC	-	Plant Description
OrgCarbon	-	Organic Carbon
TotN	-	Total Nitrogen
AvailP	-	Available Phosphorus
AvailK	-	Available Potassium
ECon	-	Electrical Conductivity
DBH	-	Diameter at Breast Height
TAGBIOMASS	-	Total Biomass
N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
CA	-	Calcium
MG	-	Magnesium
TPY	-	Total pulp yield
KAPPA	-	Kappa Number
CWS	-	Cold Water Solubles
HWS	-	Hot Water Solubles
ABS	-	Alcohol Benzene Solubles
SHS	-	Sodium Hydroxide Solubles
BF	-	Burst Factor
TF	-	Tear Factor
DF	-	Double Fold

Acknowledgement

The author is grateful to Prof. K. Udayan and Prof. S. Manian, Bharathiar University for providing Laboratory facilities.

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Digitization and Automation of Tropical Forest Biomass

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Abstract: Digitization and Automation of Tropical Forest Biomass is developed for planners of forest inventories, scientists, scholars and forest officials involved in finding and comparing the biomass of the tropical forests throughout the world.

Climate change is one of the global issues of our time, and forests play an important role in it. Changes in the cover, use, and management of forests produce sources and sinks of carbon dioxide, which are exchanged with the biosphere. Estimation of the magnitude of these sources and sinks requires reliable estimates of the biomass of forests. It was with this idea the present investigation was undertaken access the biomass of tropical forests. It also focuses on tropical forests whose high potential biomass gives any changes taking place in them a particular significance and it is concerned with one important component of the total biomass, including ground woody biomass in trees.

Besides this the present investigation aims to maintain Bioinformation techniques and concepts in tracking forest biomass density in a more simpler and effective way using Visual Basic 6.0 as the Frontend Tool and SQL Server / Oracle / Ms-Access as the Back end Tool. The study tries to maintain a catalog of important tropical forest biomass in a more efficient and consistent manner and compare the forest type, country, continents and climate for the biomass accumulation in different forest types.

Keywords: Digitization, Automation, Biomass, Tropical Forests, System Overview, System Design, Testing and Implementation.

Introduction

Tropical Forest Biomass

Forests have traditionally been used for many products including timber, fuel and fodder. Determining the biomass of forests is a useful way of providing estimates of the quantity of these components. (FAO, 1997).

Biomass is a useful variable for comparing structural and functional attributes of forest ecosystems across a wide range of environmental conditions (Brown, *et al.* 1989, 1991). Biomass estimates for tropical forests have been made by the FAO (1993) based on the FAO FORIS (Forest Resources Information System), a computerized database. Biomass estimates were computed from estimates of volume over bark (VOB, inventoried volume to a minimum tree diameter of 10 cm) often measured in forest inventories (Brown & Iverson, 1992). The compilation of VOB database by the FAO required much-educated guesswork to produce estimates on a tropic-wide basis (Gillespie *et al.* 1992). This approach is therefore of unknown reliability and any errors in VOB estimates were compounded during the conversion of these data to biomass values. However, new efforts are in progress to estimate biomass more directly from forest inventory data, which would provide more reliable data for assessment of the quantity of forest resources.

The literature review on the biomass of tropical forests evaluates the application in the existing data or where the detailed data is lacking. It would emphasize the need for improved biomass estimates. Since there is a common interest in the forests biomass and the information provided by the present study would be a complement to the existing information.

Overview of Client-Server Architecture

The Client / Server application architecture which allowed to run on both the workstations and the server, was introduced to address issues of cost and performance. In this architecture, two separate applications independently could work together to complete a task, and implemented its conceptions SQL based Data Base Management System (DBMS). Unlike the file server, the request that goes out to the server is not simply a request for a file in the form of disk input / output request which are returned as series of input / output blocks. Instead actual instructions can be communicated to an application running on the server and the server can execute these instructions itself and send back a response.

Client / Server refers to a process involving at least two independent entitie's viz. client and the server. The Client makes the request to the server and the server services the request. A request may take the form of an SQL (query) submitted to an SQL / Oracle database design which in turn processes the request and returns the result set.

System Overview Objective of the System

To develop a model for accessing the biomass per hectare estimates to many tropical countries.

To maintain Bio Information Techniques and concepts in Tracking Forest biomass details in a more simpler and effective way using Visual Basic 6.0 as the Front end Tool and SQL Server / Oracle / MS- Access as the Back end Tool.

The project has been architected as Client / Server Architecture, on which the client can be independent to the Second tier. Client can send a request to second tier (the second tier will be a database part), so that second tier can able to accept the request. It could be of any Database design. Once the database design gets repaired; application user can replace the Database design.

Present System Overview

Since no system is available for quick reference to researchers. The present system or model is more flexible, and reliable, consistent and time saving to facilitate the quick-reference; information search.

Efficient algorithm has been used for querying the data which also reduces the data mining time. Data updating and deletion is also possible in the proposed system. However, authenticated users alone can able to use this system.

Features of the Proposed System Overview

Low cost and easy maintenance.

Simpler user interface.

Consistently with the database.

File server architecture allows adding and reducing computer resources as and when needed.

Transaction happens successfully and therefore no change of incomplete transaction is possible.

Hardware and Software Specifications

System Requirements

This system is developed on Microsoft Windows 98 operating system compatible with win 9x. It is highly user friendly. This system has been developed in the famous and powerful front end Tool, viz. Microsoft visual studio 6.0 Enterprise edition and the powerful and reliable Oracle 8.0/SQL Server/MS-ACCESS as the back end tool.

Hardware Requirements

Processor	Intel Pentium and Above
RAM	32 MB and Above
Hard Disk Capacity	4G and Above

Pointing Device Serial or PS/2 is recommended.

Software Requirements

Operating System Win 9X, Win NT

Front End Tool Visual Basic 6.0 Enterprise Edition

Back End Tool Oracle/SQL Server/ Ms-Access

In a Client/ Server system there will be two different entities. A Server that serves the request and a client that makes the request. Two Tier Client/Server Architecture revolves around a desktop machine operating as client, network server housing the back-end database engine. Logic is split between these two locations, the client and the server. In a two- tier model, the front-end piece is commonly being development in power builders, Developer 2000, Visual Basic (or) Some Other 4GL. The key point to remember is that, in a two-tier model business logic for the application must physically reside on the client (or) be implemented on the back end within the DBMS in the forms of triggers and stored procedures.

Back End

Oracle and many other database systems are used for Client/Server Computing. The release 8 is based on the relation model as well as object oriented concepts and features which is termed as (ORDBMS). It allows sharing of data by multiple users or applications (Client/ Front end) by allowing them to concurrently access a centrally maintained database server (server/Backend). At the same time it protects the database from unauthorized users by implementing various security measures. It runs virtually on every kind of computer. Still it functions identically of all these machines. Therefore it makes our applications more portable (Date, 1998).

Structural query languages (SQL) is a data sub language. It interfaces with a relational database statements and instructions to the database. The SQL in used for general purpose programming language like C and Basic (Johnson, 1997).

System Design

The Database allows data to be shared among, different applications. In addition to responsibility for designing files, determining their contents, and selecting appropriate methods for organizing the data analysts must design the means of interaction with organization databases.

The basis of database management drawing on the relationships among data and the sharing of data across different applications are examined. Entity relationships are described by their dependence on each other, as well by the extent of the relationship.

ER Diagrams

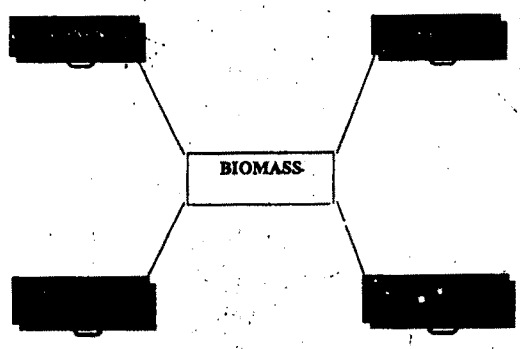

Fig. 1: Entity Relationship model for Biomass Density.

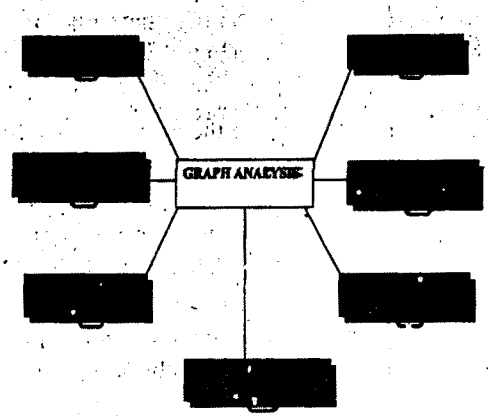

Fig. 2: Entity Relationship Diagram

Tables Design

The Database has two tables. Table 1 will occupy the actual records. Temporary table is used for calculating the average value obtained from the output. By creating the temporary table the efficiency can be increased.

Table 1: Forest (Contain the actual records)

Parameters	Type	Description
Continent	Text	Continent
Country	Text	Country it belongs to.
Forest Type	Text	Forest Type it belongs to.
Climate Cont	Text	Climate it belongs to.
Biomass Value	Numeric	Min Biomass Value.
mBiomass Value	Numeric	Max Biomass Value.

Table 2: Temp (Contain Temporary record value obtained from result)

Parameters	Type	Description
Continent	Text	Continent
Country		TextCountry it belongs to.
Forest Type	Text	Forest type it belongs to.
Climate Cont	Text	Climate it belongs to.
Biomass Value	Numeric	Min biomass value.

The Table 1 & 2 doesn't have any primary key. Since it uses candidate key (combination of 2 or more keys which uniquely identifies the record). This package doesn't identify the single record with the help of single attribute, so candidate key is the suitable option.

If user wants to calculate the average value from the results obtained, again certain constrained has to be forced for the existing queries and we cannot optimize the queries to get the output, so time efficiency will be increased. In order to solve these problems temporary Table 2 will be maintained and the average values will be calculated by posing the queries on the temporary tables, so that there would be drastic change in time complexity and time complexity would decrease.

Screen Shots

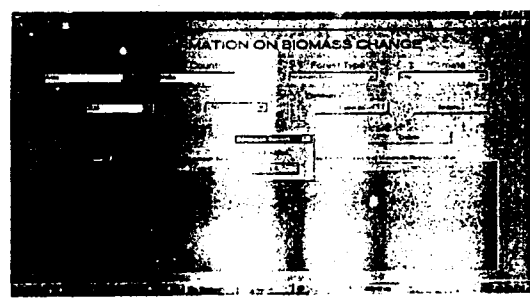

Fig. 1: Adding the New Record

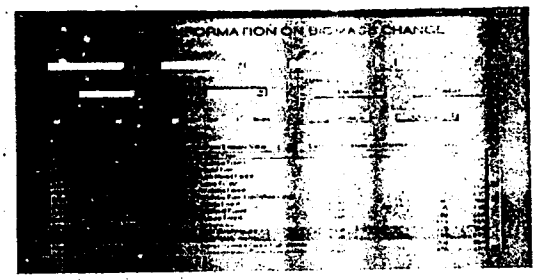

Fig. 2: Viewing the World Statistics

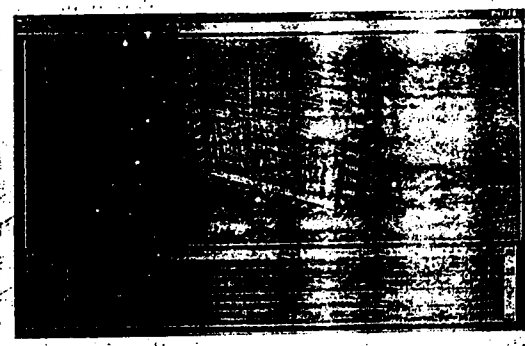

Fig. 3: World Details (3D- BarGraph)

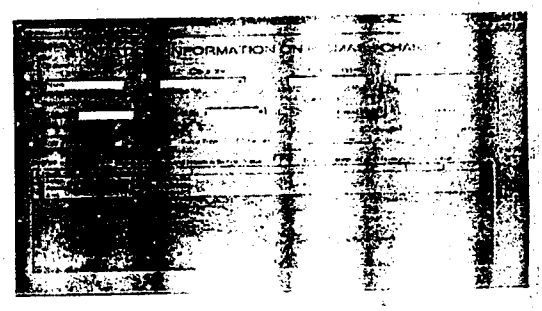

Fig. 4: Viewing the World Wi[illegible] continent average

Fig. 5: Viewing the World Wide continent average (Pie Chart-3D)

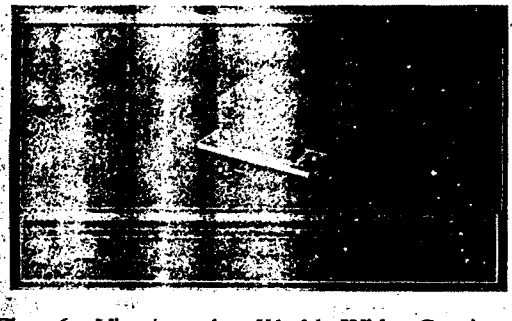

Fig. 6: Viewing the World Wide Continent Average (Area Graph-3D)

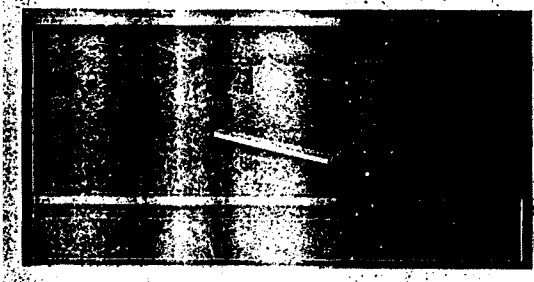

Fig. 7: Viewing the World Wide continent average (Step 3D Graph)

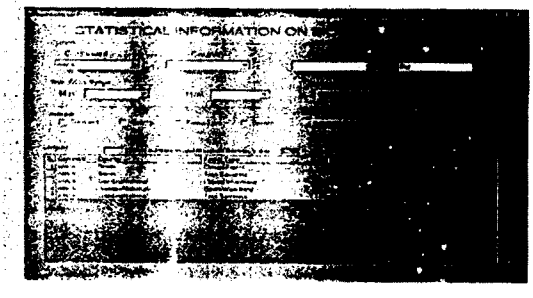

Fig 8: Viewing information on Continent-Climate

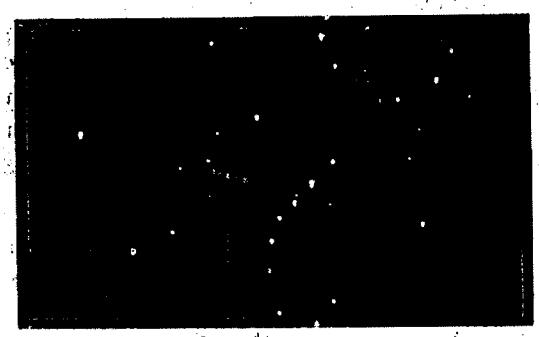

Fig. 9: Viewing information on Continent-Climate

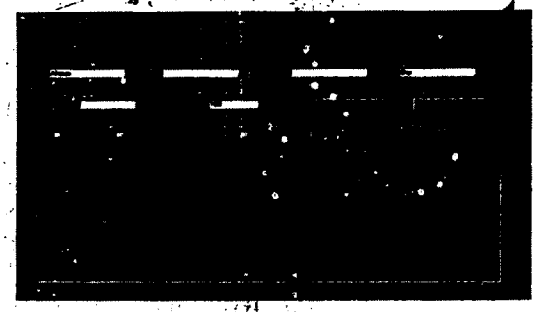

Fig. 10: Viewing information on Continent-Climate with Max Value

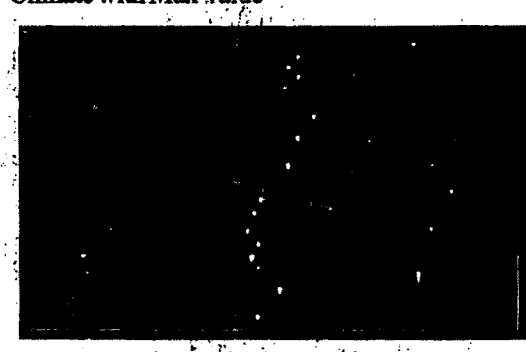

Fig. 11: Viewing information on Continent-Climate with Max Value (Bar Graph-3D)

Testing and Implementation

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Black Box Testing

The technique was employed to identify the initialization, termination and for the correction of error. In order to make the testing process more effecient the test cases with the more efficient input data are created to demonstrate that both components & the total system would satisfy all the design requirements.

Conclusion

The present information reduced the manual work in calculating the biomass density the time taken to compute the biomass is very fast by comparing the history data too, Research institute, colleges and for the forest department, the package is very useful. In future this package can be extended in network side by sharing the instant ideas across the world. Since the data is minimum, there is no need for mining the data. In case, if huge number of data is present a suitable technique has to be adopted to mine the data. Several databases available in the world can be clubbed together and then suitable decision can be presented as per the requirement, through Data warehousing.

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IV

Litter Production and Nutrient Return in Teak Plantation

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Introduction : Investigations on litter production and nutrient return in natural forests as well as in plantations remain one of the important aspects of nutrient cycling. In natural forests and man made protected plantations, cycling of nutrients is an important aspect, since considerable amount of nutrients are returned through litter fall in the form of leaves, twigs, bark, branches, flowers, fruits etc., and are made available for reabsorption. Litter also has important effects on soil physical properties. Organic matter reduces bulk density, increases water holding capacity and cation exchange capacity [10]. Litter accumulation also check weeds, protects the soil from the erosive impact of rain and reduces surface water run off [20].

Soil and vegetation have a complex inter-relationship. Vegetation influences the soil properties whereas soil properties influence vegetation type. Selective absorption of nutrient elements by different tree species and the capacity to return to soil bring about changes in soil properties. In order to understand the functioning of forest ecosystem, detailed studies on nutrient cycling are of paramount importance. Litterfall thus exerts an important influence on physical, chemical and biological characteristics of soil.

Investigations on litter production and the amount of important nutrients recycled through the litter in *Tectona grandis*, in natural and plantations are very meagre [9], in comparison to those for tropical tree species [4, 17] and for temperate zones of the world [3]. Teak (*Tectona grandis* L. f) is a unique species whose timber is most valuable amongst the timbers of the world. Due to durability and decorative nature it is used as a major source for all construction and furniture purposes. The difference in climate and the nature and growth patterns of tropical and subtropical tree species interalia require carring out such ecologically important studies. Therefore an investigation was conducted to assess litter production and nutrient return characteristics in teak plantations.

Material and Methods

Study Site : The study covered an area of forest and plantations of *Tectona grandis* located at Talavadi, Erode District, Tamil Nadu State lying between latitude 11° 28′ and 12° E and longitude

Van Vigyan, Vol. 36, No. 2, 3 & 4, Pages 128-133.

76° 59' and 77° 47' N at an altitude of 540 m above mean sea level. This area has red soil with a pH of between 6.5 and 7.0. The maximum soil N, P, K, Ca and Mg were 3240, 140, 2660, 1300 and 1680 kg h^{-1} respectively. The mean temperature 40°C and the mean annual rainfall about 600 mm.

Plantation Details : The sampling area (3 hectares) is a plantation of pure teak stands. Density was 628 trees h^{-1}. The mean height was 16 m during 9th year and dbh 76 cm.

Litter Determinations : Twenty litter traps of 1 × 1 m were laid down randomly throughout the sampling area. The litter traps were made by enclosing the area with nylon thread. All the quadrats were initially cleared and swept of any deposited debris. Litter was collected at monthly interval from January 1996 to December 1997 for one year. The litter was then separated into different components like leaf, twig, bark, fruit, flower etc., wherever possible. They were dried in oven at 80°C and the dry weight of the litter was recorded. From the sample oven dry weight the total dry weight of the litter was calculated.

Nutrient Analysis : A composite litter sample was also taken at all the intervals for the chemical analysis. These litter samples were oven-dried after washing with acidulated (0.05 NH_4Cl) water followed by distilled and deionized waters. The dried sample was powdered and passed through 0.5 mm sieve. The sample was analysed for nitrogen, phosphorus potassium, calcium and magnesium by following standard chemical analysis methods [2, 11].

Results and Discussion : Estimation of litter production (litterfall) was carried out for one year in the plantation and the results are presented in Table 1. It was observed that, of total litter (10, 175 kg/ha) 91.48 per cent was contributed by leaf, 6.85 per cent by twigs, 1.66 per cent by reproductive parts and 0.001 per cent by bark. Litterfall occurred from January to December. The litterfall showed Unimodel pattern having a peak in the months of February and March, i.e. early summer season due to markedly high atmospheric temperature that hamper normal metabolic processes and as a consequence, the growth during the season of each year [1, 12] However, biomodel pattern of litter production was observed in bamboos [5, 16, 18] in *Eucalyptus* [6], in *Acacia* [12, 15].

Regarding twig, bark, and reproductive parts litterfall no definite trend has been observed. With regard to the per cent contribution of litter components, the results obtained in the present study is comparable with the deciduous plantations [7, 18]. The contribution of leaf-litter to the total litter, was 76–92% which is comparatively much higher than the bamboo plantations [18]. The variations in the values of total amount of litter fall, may be attributed to variations in the age of

Table 1. Litter production (t ha^{-1}) in teak plantations.

Components	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Leaf	0.427	2.792	3.457	0.299	0 201	0.221	1.028	0.401	0.212	0.179	0.160	0.157	9.333
Twig	—	—	0.024	—	0 045	0.037	0.388	0.014	—	0169	—	—	0.677
Bark	—	—	—	—	0 001	—	—	—	—	—	—	—	0.001
Reprod. parts	—	—	0.028	0.014	0.000	0.015	0 098	—	—	—	—	—	0.164
Total	0.427	2.792	3.509	0,313	0 256	0.273	1.514	0.415	0 212	0.348	0.180	0.157	10.175

plantations, climatic conditions, site characteristics and density of tree cover [16].

Nutrient Return : Nutrient composition of the litter is regarded as a measure of the intrinsic quality (decomposability) and environmental characteristics of the soil and climate, which in turn affect the release of the important nutrient elements through decomposition. The nutrient concentration in various litter components presented in Table 2. Since there was not much variation in the nutrient concentration of litter components during various months of the year, the average values were taken into consideration for further discussion. It revealed that in leaf, twig and reproductive parts, nutrients found in the order of Ca > K > N > Mg >P, whereas in bark Ca > N > Mg > K > P. These results are in contrast with those obtained from *Eucalyptus globulus* [22], *E.* hybrid [6, 7]. *Bambusa bambos* [18], *Acacia holosericea* [1] wherein the highest concentration of all the nutrients was in leaf and the highest concentration was for Nitrogen. The elemental concentration in twig was in the order of K > N > Mg > Ca > P [18].

Table 2. Nutrient concentration in litter components (%)

Litter components	N	p	K	Ca	Mg
Leaf	1.90	0.02	1.31	2.24	0.32
Twig	0,60	0.02	0.83	1.34	0.20
Bark	0.13	0.01	0.20	2 56	0 29
Reproductive parts	0.30	0.02	0.86	1.34	0.21

It was observed that 136.94, 1.65, 114.86, 215.68 and 118.32 kg h^{-1} N, P, K, Ca and Mg respectively was returned through litterfall (Table 3). The maximum amount of all nutrients was returned through leaf-litter and minimum by bark. Almost similar results were also obtained from natural forests and plantation ecosystems [6, 7, 14, 15, 16, 18, 21, 22].

Table 3. Nutrient return (kg h^{-1}) in teak plantations.

Components	N	P	K	Ca	Mg
Leaf	134.10	1.38	107.10	209.46	117.00
Twig	1.78	0.10	4.55	3.85	0.98
Bark	0.006	0.001	0.002	0.026	0.003
Reproductive parts	1.05	0.18	3.21	2.34	0.34
Total	136.94	1.64	114.86	215.68	118 32

Conclusion : Study of litter production litter nutrient status and differential pattern of nutrient returns through litterfall is important, especially in conservation of nutrients in the management of short rotation forestry on a perpetual basis [14]. Although the annual uptake of nutrients by vigorous stand of trees approaches that of an agricultural crop, on an area basis, a

large percentage of the absorbed nutrients are returned to the forest floor as leaching from forest canopy (or) litterfall. The slowly decomposing litter releases nutrient for re-use by the forest stand, so that only small additonal amounts of nutrients are needed to sustain tree growth and bole wood production. Some of the fast growing species are efficient in absorbing nutrients from deeper soil layers and help them to accumulate in top soil through litter fall, which eventually improves the soil physical and chemical conditions.

The results are also a pointer that necessary safe guards are to be taken under these plantations to maintain the nutrient status of the soil as well as ecosystem balance.

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BIOPRODUCTIVITY AND NUTRIENT CONCENTRATION IN *PHYLLANTHUS MADERASPATENSIS Linn.*

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ABSTRACT

The present investigation deals with the bioproductivity, nutrient distribution and energy accumulation in a herbaceous vegetation at Bharathiar University Campus, Coimbatore . The bioproductivity study revealed that leaves contribute maximum biomass (25 to 34 percent), then stem (10 to 15 percent). The accumlation of biomass is in the order of leaves> stem> seed> roots> branches. The proportion of nutrient elements was found in the order of leaves- N>K> Mg> Ca> P, branches, seed, stem and roots-K>N>Mg> Ca>P. Among the concentration of different nutrients in various biomass components, the highest concentration (N,Ca and Mg) was observed in leaf. Branches contain maximum concentration of P and and K. The maximum energy content is observed in stem (2730 cal. g^{-1}) and minimum in root (2540 cal. g^{-1}). The results are discussed with earlier reports.

Key Words : **Bioproductivity; Nutrient Conccntration; *Phyllanthus maderaspatensis***

INTRODUCTION

Bioproductivity is an important biological phenomenon of nature in which the entire diverse array of life depends, either directly or indirectly. The importance of bioproductivity studies in aquatic and terrestrial ecosystems is well realized in view of its value in estimating the productive capacity (Thakur *et al.,* 1999). It provides an assessment about the exact nature of the ecosystems, its tropical level and the availability of energy for secondary producers. It is also important to measure the organic matter production in ecosystems under various climatic zones to get information on the effect of various ecological factors on productivity of plants (Paliwal *et al.,* 1999).

The semi-arid tracts of Western Ghats are dominated by savannah to pure grasslands, herbaceous and shrubby vegetations . Most of these are often subjected to fire and grazing, leading to heavy loss of water and soil, resulting in enviromental degradation. Productivity of the individual ecosystem is highly variable. Information was avilable on primary productivity of the individual ecosystem is highly variable. Information was available on primary productivity of grasslands and shrubby vegetations of Southern (Pailwal *et al.,* 1989, Karunaisamy, 1992, Shanmughavel, 1993, 1994,1995 and Anbazhagan, 1994), Northern (Singh and ?Yadava, 1974), Eastern (Misra and Misra, 1984) and Northeastern (Ramakrishnan and Ram 1987) India.

Shrubs and herbs, which come up very fast on the abandoned grasslands of clear felled areas, have largely been

considered problematic without being subjected to any practical utility, though they augment grazing value and ameliorate the soil. They not only form an important stage in the primary and secondary successions, but also act as soil binders, increase the total carbon fixation of the community, improve soil quality, provide fodder and fuel to the rural masses (Crow, 1977). In addition, herbs and shrubs easily establish themselves on poor sites and stony soils. Thus, the vast barren woodlands are certainly better suited to herbs and shrubs rather than exotic trees of unpredictable performance. Simultaneously, shrubs and herbs are capable of producing larger biomass per unit area per year than trees planted in these areas (Thakur *et a.,* 1999).

Distribution and circulation of mutrients play a very importamt role in forests and plantation ecosytems. These circulate in relatively large amounts within the ecosytems. Much of the nutrient uptake by the vegetation is returned to the soil by way of litter fall, etc., but an appreciable amount is retained by the bole, branches, leaves, rhizome, roots which are usually harvested and removed from the site (Shanmughavel, 1995). This loss of nutrients is greater with intensive utilization of fast growing short rotation species.

The study on biological productivity and distribution of nutrients is, therefore, necessary with a view to maximising the productivity from our limited forest areas. Therefore, the investigation is mainly aimed at evaluating the bioproductivity of the herb *Phyllanthus maderaspatensis* Linn. vegetation and the distribution of nutrients in its biomass components.

Further, the dynamics of energy transfer is another key function in an ecoystem and, in the pyramid, trapping of radiant energy by the photosynthesizing organisms occupies the first step. This can well be understood incase of aquatic and terrestrial systems. Since, the efficiency of ecological energy conservation varies with spatial and temporal variations and changes in vegetation composition, it becomes of prime interest to evaluate this function in specified habitats. In the current study, in addition to biomass production, the energy conservation in the herbs is also evaluated.

MATERIALS AND METHODS

STUDY SITE

The study site is located at Bharthiar University Campus, Coimbatore, which is an important city of Tamil Nadu. It is situated at an altitude of 426.72m above mean sea level. It is located 11.04" E of longitude and 76.93" N latitude. The pH of the soil is 8.3. The electrical conductivity is 0.12 ms cm $^{-1}$. The maximum soil N,P, and K is 88 Kgha^{-1} and 330 Kgha $^{-1}$.

CLIMATE

There are three distinct seasons in a year, viz., Summer (March-June) -Rainy (July- October) and Winter (November-February). The maximum temperature is 34^{0}C and minimum 17^{0}C; Annual precipitation, 820 mm; Relative humidity, maximum 92% and minimum 55%

1. Number and Shape Of Quadrats

Ten quadrats were randomly taken for this study. The size of the quadrat was 1mx1m.

2. Harvesting

Harvesting was done twice a month. All the shoot materials within the quadrat were collected and removed by reaping to ground level. Harvested shoots together with all loose dead materials were sealed in the labelled polythene bags. The same area was never harvested for more than one time during the study period.

3. Digging

For the estimation of root biomass, pits were dug out in the quadrat area. The size of the pit was 25x25x30 cms. The soil samples were collected from the study area and tested for pH, Electrical conductivity, N,P, and K. The roots were washed and kept in the labelled and sealed poiythene bags.

4. Drying

The collected fresh shoots and roots were dried at a temperature of 80^0 C for 48 hours in a hot air oven. The dried samples were weighed again and again till the concordant values were obained.

5. Soil Sampling

Soil samples were collected from the study area and spread on labelled petriplates, dried under room temperature and kept in polythene bags.The samples were analyzed in the soil testing laboratory, Tamil Nadu Agricultural University, Coimbatore.

6. Meteorological Data

For the study site, data during the period were collected from the nearby agriculture office.

7. Energy Accumulation

Dried material was crushed to fine powder and the calorific values were determined using oxygen bomb calorimetry, as described by Leith (1975).

8. Nutrient Analysis

Nitrogen and Phosphours were estimated as described by Armstrong et al., (1967). The nutrients K, Ca, and Mg were analyzed using an atomic absorption Spectrophotometer, Perkin Elmer 5000 USA (Issac and Johnson 1975).

RESULTS AND DISCUSSION

Inspite of a greater Interest of the ecologists in the production of organic matter in different ecosystems, work of this

nature on the herbaceous vegetation is scanty as compared to tree species. A forest community represents a complex structure and varies from area to area, depending on soil, geology, gradient, microclimate as well as the management practices being followed. Depending on the composition of a forest community, the diversity of herbaceous vegetation, its production of biomass also varies significantly.

The oven dry weights of individual components of *Phyllanthus maderaspatensis* Linn. are summarized in Table 1, derived from field values as in the 10 quadrats (Table 4). There were considerable differences between fresh weights and dry weights of *Phyllanthus* species and their biomass components. In most of the above ground components the moisture loss ranges between 58 to 64 percent upon drying. However, in case of reproductive organs, it was 75 percent. The below ground parts, i.e., roots, the moisture content varied from 62 to 82 percent. Almost similar results were also observed by Sharma and Srivastava (1984), Shanmughavel (1989), Angazhagan (1994) and Kumar and Singh (1984).

It is very interesting to note that leaves contribute maximum biomass (25 to 34 percent) followed by stem (10 to 15 percent). The accumulation of biomass was found in the order of leaves > stem > seed > roots > branches. However, most of the tree species and some herb and shrub species, the accumulation pattern of biomass was found in the order of stem > branches > leaves > reproductive parts > root (Negi and Sharma, 1984; Negi, 1984; Mathur *et al.*, 1984; Shanmughavel, 1989). This difference in the accumulation of

biomass may be attributed to the differential growth pattern of this *Phyllanthus* species.

For proper understanding and management of the herbaceous vegetation, the total biological approach necessitates the knowledge of nutrient status of the individual species of the ecosystem (Negi and Sharma, 1984). The average nutrient concentration (mg/g-1) of various biomass components of *Phyllanthus maderaspatensis* Linn. is presented in Table 2. It has been observed that the percentage composition of various nutrients in different biomass components varies consisderably in herbaceous vegetation. Considering the concentration of different nutrients in the various biomass components, the highest concentration of N, Ca and Mg was observed in leaf. Branches contained the maximum concentration of P and K. The proportion of nutrient elements in leaf is in order of N>K>Mg>Ca>P, branches, K>N>Mg>Ca>P, stem, K> N> Mg>Ca> P, seed K> N> Mg> Ca> P and in root K> N>Mg> Ca> P. These results are in general agreement with those reported earlier for tree species (George, 1977; Turner and Lambert, 1983; Shanmughavel, 1989, 1995; Anbazhagan, 1994, 1998). Dissimilar results have also been reported (Negi and Sharma, 1984; *et al.,* 1975).

The efficiency of accumulation of energy in different aquatic and terrestrial species differed as the heat of combustion and percent weight of dried material showed wide variations. The amount of solar energy stored in plant biomass depends upon the type of sepcies (Ovington and Heitkemp,

1960) and time of collection and ecological habitat (Golley , 1961). The energy content of different biomass components of *Phyllanthus maderaspaternsis* Linn. is summarised in Table 3. The maximum energy content is observed in stem (2730 cal. g^{-1}) and minnimum in root (2540 cal. g^{-1}). The material taken for this study was during winter season. Mc. Nair (1995) reported that, with decrease in temperature, there was a corresponding increase in the calorific values of plants in the terrestrial system. The results of this study substantiate this statement.

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TABLE-1

Biomass Accumulation of *Phyllanthus maderaspatensis (%)*

Quadrat Number	Leaves	Branches	Seed	Stem	Total above ground mass	Root	Grand total biomass
1	25.6±1.7	4.21±0.8	3.73±1.5	12.01±0.7	45.5	6.68±0.5	52.25
2.	27.8±1.5	2.72±0.9	3.77±1.4	12.45±1.2	46.74	6.95±0.4	53.69
3.	36.7±1.0	3.85±1.0	5.30±1.0	13.48±1.0	59.34	6.20±0.5	65.54
4.	33.9±1.3	4.54±0.8	4.52±1.2	15.89±0.5	56.86	7.23±0.6	66.18
5.	32.3±0.8	4.00±0.9	5.42±1.0	14.02±0.7	55.76	6.45±0.8	62.21
6.	31.5±1.4	3.93±1.0	6.10±0.9	13.76±0.9	55.30	6.33±0.7	61.63
7.	28.2±0.7	3.41±0.7	3.62±1.0	12.25±0.8	47.50	5.64±0.5	53.14
8.	24.4±0.8	3.03±0.8	3.13±1.0	10.60±0.7	41.46	4.88±0.8	46.04
9.	34.0±1.4	4.22±0.9	6.28±1.0	14.78±0.9	59.22	6.80±0.5	66.09
10	29.6±0.9	3.66±0.9	5.12±0.9	12.83±0.8	51.22	5.91±0.7	57.13

Different components of herb such as leaf, branch, bole and root were collected individually and their fresh weight was taken in the field. They were dried at 103±2°C for dry weight determination. The percentage contribution of individual tree component was calculated. The contribution was found to be in the order of Leaves>Stem>Seed>Roots>Branches.

TABLE - 2

Nutrient Concentration in Biomass Components of *Phyllanthus maderaspatensis* (%)

Nutrients Mg/g-1	Leaves	Branches	Seed	Stem	Root
N	7.3±0.5	7.0±0.2	3.5±0.3	7.0±0.4	6.0±0.9
P	0.7±0.6	0.8±0.1	0.3±0.4	0.7±0.3	0.6±0.5
K	6.5±0.7	7.9±0.1	3.8±0.1	7.5±0.6	6.8±0.6
Ca	4.0±0.5	3.0±0.9	1.0±0.9	3.0±0.5	2.3±0.4
Mg	4.5±0.7	3.5±0.8	1.5±0.8	3.5±0.8	3.5±0.7

Results are the averages of three independent observations. Since there was little difference between observations, average values are given.

TABLE - 3

Energy Contnet of Biomass Components of *Phyllanthus maderaspatensis*

Biomass components	Energy content (dry weight) (Cal. G-1 w+)
Leaves	2600 ± 13
Branches	2683 ± 11
Seed	2300 ± 10
Stem	2730 ± 16
Root	2450 ± 11

The results are the averages of three independent observations.

TABLE - 4

Data of Biomass Components Recorded

Data No.	Number of Branches	Shoot Length cm	Root Length cm	Total Lenght cm
1	6	21.9	9.3	31.2
2	3	22.8	10.2	33.0
3	5	30.6	13.4	44.0
4	4	29.0	9.7	38.7
5	8	35.2	14.7	49.9
6	2	25.5	9.4	34.9
7	5	31.4	40.2	71.6
8	4	40.4	24.4	64.8
9	5	19.2	14.1	33.3
10	3	20.1	18.7	38.8

Naumber of Branches

Standard deviation = 14.62 ± 1.92

Mean = 20.24

Shoot Length

Standard deviation = 8.41 ± 1.1

Mean = 25.22

Root length

Standard deviation = 6.65 ± 0.87

Mean = 14.57

Total Length

Standard deviation = 11.7 ± 1.54

Mean = 39.5

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16

BIOMASS PRODUCTION AND NUTRIENT DISTRIBUTION IN *EUCALYPTUS* HYBRID PLANTATIONS

P. SHANMUGHAVEL, K. FRANCIS AND ZHENG ZHENG

TREE farming is very important in India as the forests are degraded. It will help in attaining the ideal forest covers of 60 per cent and 20 per cent in hills and plains respectively (Banarji *et al*, 1990). In order to achieve this, efforts have been initiated for raising large-scale plantations of short rotation exotic species. *Eucalyptus* species is suitable for plantations because they are suited to a variety of climatic and edaphic conditions (Otegbaye and Sameraiviza, 1990). *Eucalyptus* hybrids have been grown on Bharathiar University campus and are important in afforesting some of the barren areas.

Studies on various aspects of *Eucalyptus* species, for example, on the survival and growth rate, timber and fuel yield, nutrient content and cycling have been reported (Banarji *et al*, 1990; Otegbaye and Sameraiviza, 1990; Nandi *et al*, 1991; Pattanaik and Vijaya Kumar, 1997; Islam *et al*, 1997; Sharma, 1997). This paper presents results of study on biomass estimation and nutrient distribution in a nine-year-old *Eucalyptus* hybrid plantation at Bharathiar University.

MATERIALS AND METHODS

Study Site

The study site is located at Bharathiar University Campus, Coimbatore. It is at an altitude of 426.72 MSL located at 11.04' E longitude and 76.93' N latitude. The climate of the area is monsoon. The area has red soils with pH between 7 and 7.8. The electrical conductivity is 0.2 M Scm–1. The average soil nitrogen, phosphorus and potassium were 98, 7.6 and 115 kg/ha, respectively. The average annual temperature and rainfall was 31.5o C and 117.5 mm, respectively.

Eucalyptus *Hybrid*

The *Eucalyptus* hybrid known as Mysore Gum or *Eucalyptus tereticornis* is the most widely planted eucalyptus in India.

Establishment and Management

The plantation was established using containerised seedlings. Seedlings of 2.5 cm height picked out from the polythene bags were transplanted at a spacing of 2 × 2 metres in three hectares at 2,500 seedlings/ha. The transplanted seedlings were watered regularly in the morning and evening. Care was taken to avoid waterlogging. No fertiliser was added. Weeding was done by hand as and when required. After one year, the plantation was irrigated at 15-day intervals. The plantation was protected against damage by grazing and browsing animals by making fences. About 70 per cent of the seedlings were established

Biomass Estimation

Field studies were conducted using the tree harvesting method for biomass estimation (Islam *et al*, 1997). In the nine year old plantation, six sample plots measuring 0.25 hectare were enumerated and the diameter at breast height (DBH) were recorded. The diameter range was divided into three classes (A, B, and C) depending upon the distribution of trees. Two sample trees were felled and the fresh weight of all components—leaf, twig, branch, bole, bark—were measured in the field using a balance. Bark was removed manually. To determine underground biomass, roots were excavated completely by making a trench around the main stem. Representative samples of all the plant parts were oven dried at 80o C to obtain their oven-dry weight (Islam *et al*, 1997). The standing biomass (kg/ha) was obtained by multiplying the dry weights of the sample tree by the number of trees in the respective diameter classes followed by summation of biomass in each diameter class.

Estimation of Nutrients

Nitrogen and phosphorus were estimated as described by Armstrong (1967) using the Technicon Auto Analyser II (Gedko International. U.K.). The samples were digested in a Kjeldatherm digestion system (KT 408 Bonn) at 400° C for three hours. One-gram samples were digested in digestion tubes with both 2.5 g potassium sulphate and 5 m H_2SO_4. After digestion and cooling, the digested sample was made up to 50 ml with distilled water and used for analysis of N and P. The nutrients K, Ca and Mg were analysed using an atomic adsorption Spectrophotometer (Perkin–Elmer, 5000, U.S.A.) after wet digestion of 1 g sample with triple acid mixline (10 ml conc, Hno3, 4 ml HCL O4 and 1 ml conc. Hill). The digested samples were filtered through Whatman No. 42 filter paper and made up to 100 ml with distilled water and this solution was stored and used for analysis (Gupta and Raturi, 1984). All analysis was performed on the average of three replicates.

RESULTS AND DISCUSSION

Individual Tree Dimensions

The nine-year-old plantation was raised in Bharathiar University under similar edaphic and climatic conditions, with no associate trees either in the tree canopy or as undergrowth except some annuals and grasses. However, there is wide variation in the growth of trees (Table 1). The mean crop diameter and height increased with increase in the diameter class. Thus the mean diameter increased from 4.5 cm (diameter class A) to 9.5 cm (diameter class C). Similarly the mean crop height was lowest in diameter class A and highest in diameter class C, the values being 8 metres and 13.9 metres, respectively. The variations in biomass within the same plantation are

TABLE 1
Range of Diameter Class and Sample Tree Parameters

Diameter Class	Range (cm)	D. B. H. (cm)	Basal Area (cm/per tree)	Height (m)	No. of Trees
A	3-6	4.8	8.5	8.0	17
B	6-9	7.7	13.5	12.5	15
C	7-9	9.5	18.0	13.9	19

Since there are no statistically significant differences (P> 0.05) observed in the growth parameters, the value expressed is the mean of three independent experiments.

TABLE 2
Dry Weight by Tree Components of Sample Tree
(kg/tree)

D. B. H. Class	Leaf	Twig	Branch	Bark	Bole	Total AGB	Root	Grand Total Biomass
A	2.4 (5.8)	2.9 (5.0)	4.0 (6.0)	5.7 (10.6)	31.7 (72.6)	54.8	6.3 (11.5)	61.1
B	4.9 (5.7)	4.2 (4.8)	4.8 (5.5)	10.4 (12.0)	63.0 (72.0)	87.4	11.0 (12.6)	98.4
C	5.5 (5.3)	3.6 (3.5)	5.3 (5.2)	11.0 (10.8)	78.0 (75.2)	103.5	12.3 (12.0)	115.9

The values given in parentheses are per cent contribution of biomass of each component (AGB=Above-ground biomass).

attributed to various factors like genetical and site characters (Gupta and Raturi, 1984; Pandey *et al*, 1989.

Organic Matter in Sample Trees

The oven-dried matter (kg/tree) of individual components in different diameter classes are presented in Table 2. It revealed that the dry weight of all the above and below ground components increased consistently with increasing diameter class. The per cent contribution for different compounds was in the following order:

Bole > Root > Bark > Branch > Twig > Leaf

But the percent contribution of various components to the total aboveground biomass (agb) does not show any definite trend. It is seen that the per cent contribution of biomass of leaf, twig and branch decrease as the diameter and height increases. This is understandable because the other components increase in biomass at the expense of leaf biomass. The per cent contribution of bark, bole and root do not show any definite trend. The results are in conformity with the results reported

TABLE 3
Total Standing Biomass (±SE) of 9-year-old *Eucalyptus* Hybrid Plantations (kg/ha)

D. B. H. Class	Leaf	Twig	Branch	Bark	Bole	Above Ground Biomass	Root	Grand Total Biomass
A	17.0±1.0.	19.2±1.0	28.0±0.5	40.5±1.0	222.4±1.0	327.6±1.0	044.10±1.0	0371.7±0.5
B	27.7±1.0	21.1±0.5	24.0±1.0	52.3±0.5	315.0±0.5	437.2±0.5	055.20±0.5	0492.4±0.5
C	49.5±0.5	32.5±1.0	48.5±0.5	99.4±1.0	702.0±1.0	932.0±0.5	115.50±1.0	1,043.5±1.0

Each value expressed is the mean of three independent experiments.

TABLE 4
Nutrient Concentration (±SE) in Biomass Components of 9-Year Old *Eucalyptus* Hybrid

Nutrient (%)	Leaf	Twig	Branch	Bark	Bole	Root
N	1.72±0.5	0.67±0.2	0.66±0.4	0.88±0.4	0.47±0.4	0.676±0.2
P	0.10±0.7	0.07±0.4	0.08±0.3	0.09±0.3	0.05±0.3	0.08±0.4
K	0.73±0.3	0.44±0.2	0.36±0.2	0.49±0.4	0.14±0.2	0.38±0.3
Ca	1.50±0.4	0.95±0.2	0.60±0.1	2.30±0.2	0.07±0.1	0.06±0.1
Mg	0.15±0.3	0.09±0.3	0.06±0.4	0.12±0.2	0.05±0.4	0.06±0.1

Each value expressed is the mean of three independent experiments.

earlier (*Eucalyptus globules*) (Pattanaik and Vijaya Kumar, 1997; Feller, 1980; Varghese, 1990; Negi and Sharma, 1984), *Eucalyptus tereticornis* (*Banerji et al*, 1990; George, 1979; Singh and Sharma, 1976) and *Eucalyptus* hybrid (Gupta and Raturi, 1984; Pandey *et al*, 1989; Schonau and Boden, 1981).

Total Biomass

The sample tree data presented in Table 2 has been used to calculate the total biomass (Table 3). The aboveground biomass is increasing sharply from diameter class A (327.63 kg/ha) to diameter class C (932.04 kg/ha), showing the increasing effect of diameter. The rate of accumulation of dry matter (kg/ha/wt) in the non-photosynthetic components also (including roots) increases with diameter class. Diameter class C produces 1,043.55 kg Dm ha^{-1}, which is almost 2.8 times greater than the dry matter produced by diameter class A at the age of nine. Therefore, it is evident that as the age and diameter class of the plantation increases, the maximum increase is in biomass of wood followed by bark. Comparing with the studies in *Eucalyptus globulus* (6.3 t/ha/4 yr) in *Eucalyptus tereticornis* (51.1 t/ha/6 yr)(Singh and Sharma, 1976), *Eucalyptus* hybrid (100.5 t/ha/6yr) (George, 1990; Hingston, 1979; Attiwill, 1972; Art and Marks, 1971), *Eucalyptus globulus* (Stewart *et al*, 1979; Lakshmipathy, 1992), the present estimates are 6-40 fold lower. The low productivity of *Eucalyptus* hybrid in this study may be attributed to its slow growth due to climatic, edaphic and partially due to inherent low fertility of the soils. Estimates of dry matter production

Ch 19/End of Mss/Comp 14/PR/OK/BK 193

TABLE 5

Nutrition Retention (±SE) in Biomass Components of 9-Year Old *Eucalyptus* Hybrid Plantation

Nutrient (kg/ha^{-1})	Leaf	Twig	Branch	Bark	Bole	Above Ground Biomass	Root	Grand Total Biomass
N	2.90±0.2	1.2±0.2	1.80±0.3	3.50±0.6	10.40±0.2	19.80±0.4	2.90±0.4	22.70±0.5
P	0.10±0.03	0.13±0.2	0.20±0.4	0.30±0.2	1.10±0.3	1.80±0.3	0.30±0.2	2.10±0.6
K	1.20±0.2	0.80±0.3	1.00±0.3	1.90±0.3	3.10±0.3	8.00±0.1	1.60±0.5	9.60±0.3
Ca	2.60±0.3	1.80±0.5	1.60±0.5	9.30±0.3	1.50±0.2	16.80±0.5	2.60±0.2	19.40±0.4
Mg	0.20±0.4	0.17±0.4	0.10±0.4	0.40±0.4	1.10±0.3	1.97±0.3	0.20±0.3	2.17±0.3
						48.37		
N	4.25±0.2	1.41±0.2	1.58±0.3	4.60±0.6	14.80±0.2	26.64±0.4	3.70±0.4	30.34±0.5
P	0.24±0.3	0.14±0.2	0.19±0.4	0.40±0.2	1.57±0.3	2.54±0.3	0.44±0.2	2.98±0.6
K	1.80±0.2	0.92±0.3	0.86±0.3	2.56±0.3	4.41±0.3	10.55±0.1	2.09±0.5	12.6±0.3
Ca	3.70±0.3	2.00±0.5	1.44±0.5	12.00±0.3	2.20±0.2	21.34±0.5	3.31±0.2	4.65±04
Mg	0.37±0.4	0.18±0.4	0.14±0.4	0.62±0.4	1.57±0.3	2.88±0.3	0.33±0.3	3.21±0.3
						63.95		
N	8.50±0.2	2.18±0.2	3.20±0.3	8.75±0.6	32.96±0.2	55.56±0.4	7.47±0.4	3.03±0.5
P	0.40±0.3	0.22±0.2	0.38±0.4	0.89±0.2	3.54±0.3	5.43±0.3	0.89±0.2	6.32±0.6
K	3.61±0.2	1.43±0.3	1.74±0.3	4.87±0.3	9.82±0.3	21.47±0.1	4.23±0.5	5.77±0.3
Ca	7.42±0.3	3.09±0.5	2.9±0.5	22.80±0.3	4.91±0.2	41.13±0.5	6.69±0.2	47.82±0.4
Mg	0.74±0.4	0.29±0.4	0.29±0.4	1.49±0.4	3.51±0.3	6.32±0.3	0.66±0.3	6.98±0.3
						129.91		

Each value expressed is the mean of three independent experiments.

by other authors (Bradstock. 1981; Turner and Lambert. 1983) show that the major portion of the above ground biomass is contributed by the bole wood (more than 60 per cent) while leaf, branch and bark share only a small portion of the total above ground biomass corresponding with the current study.

Nutrient Concentration

The average nutrient concentration of various tree components is given in Table 4. It has been observed that the per cent concentration of various nutrients in different tree components varies considerably in these stands. Considering the concentration of different nutrients in various tree components, the highest concentrations are generally observed in leaf and bark while bole has the lowest concentration of all the nutrients. The proportion of nutrient elements in leaf, twig, branch and roots is in the order of N > Ca > K > Mg > P; bole N > K > Ca > Mg > P and bark Ca > N > K > Mg > P in all the diameter classes. These results are in general agreement with those reported earlier for *Eucalyptus* hybrid (George, 1979; Gupta and Raturi, 1984), *Eucalyptus grandis* (Bradstock, 1981; Turner and Lambert, 1983), *Eucalyptus globulus* (Feller, 1980; George, 1990, Negi and Sharma, 1984).

Nutrient retention

The total standing nutrients on an unit area basis for the plantation of age nine years was estimated from the nutrient concentration values of the sample trees. The nutrient accumulation is directly proportional to the total biomass produced in each component; therefore the percent accumulation of various nutrients will not be in the same trend. In the present case, the biomass of various components was multiplied with the respective concentrations of various elements to obtain the nutrient content in the standing crop on hectare basis as given in Table 5. It is seen in aboveground biomass that among the various nutrients, the maximum accumulation was for nitrogen followed by calcium, potassium, magnesium and phosphorus. Bole accumulated the maximum of all nutrients except calcium. Bark accumulated maximum amount of calcium (Pattanaik and Vijaya Kumar, 1997; Islam *et al*, 1997; Sharma, 1997; Armstrong *et al*, 1967). The accumulation of nutrients in aboveground biomass was in the order of Ca > N > K > Mg > P. The results of the present study were in agreement with the earlier reports (*Banarji et al*, 1990; George, 1990; Pandey *et al*, 1989; Hingston *et al*, 1979; Lakshmipathy, 1992).

The total amounts of nutrients removed by way of harvesting of aboveground biomass of the plantation at the age of nine years are 19-55 (N), 1-5 (P), 8-21 (K), 16-41 (Ca) and 2-6 (Mg) kg/ha. Thus for proper management of these ecosystems debarking in the field is essential so that the bark fraction is left over in the field. *Eucalyptus* hybrid is mainly used for pulp and fuel. The present study provides basic data on the nutrient dynamics to protect the ecosystem from degradation and allow optimal yield with the available mineral resources at the particular site. Further studies are needed so as to present a complete picture on nutrient cycling in plantation for the conservation of the environment.

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BIOMASS PRODUCTION IN A PLANTATION OF *ACACIA HOLOSERICEA*

J. ANBAZHAGAN, P. SHANMUGHAVEL AND K. FRANCIS

MOST of the land available for forestry in India is degraded land that requires high technical skills for afforestation (Chaturvedi, 1984). In order to develop appropriate silvicultural methods of planting in dry lands, an attempt was made with an exotic species, *Acacia holosericea*, in the afforestation programme near Coimbatore, India. *Acacia holosericea* Cunn. ex. G-Don is a thorn-less leguminous tree of Australian origin. It is an important fuel wood tree species that can fix atmospheric nitrogen in the root modules. It is also important in the stabilisation of shifting sands and in the prevention of sand encroachment of cultivated areas. Information available on biomass production of *Acacia holosericea* grown under afforestation programmes is meagre (Kiratiprayoon and Williams, 1981; Lamers *et al*, 1994; Ngulybe *et al*, 1993; Ovington and Madgwick, 1957). The present report aims to determine the quantification of the biomass production of *Acacia holosericea* planted under afforestation programmes.

MATERIALS AND METHODS

Study Area

This is located at the foothills of Maruthamalai (11° 1' N, 76° 93' E) near Bharathiar University, Coimbatore, at an altitude of 410 MSL with a monsoon climate. The maximum temperature was 33.5o C and the annual rainfall was 650-700 mm. The area has red soils with pH between 7-7.8 and an electrical conductivity of 0.2 dSm–1. The total soil nitrogen, phosphorus and potassium was 98, 7.6 and 115 kg/ha, respectively.

Plantation Details

Seeds were obtained from the Institute of Forest Genetics and Tree Breeding, Coimbatore. About three-month-old seedlings of 30-cm height, raised in the nursery were planted at 2 × 2

TABLE 1
Biomass in Different Parts of Three-Year-Old *Acacia holosericea* Trees

DBH	Total No. of Trees	Average of 6 Tree Samples				Total Above-Ground Biomass		Root	Total Biomass	
		Leaves (Phyllodes) (kg/tree)	Twigs (kg/tree)	Branches (kg/tree)	Main Bole	(kg/tree)	(kg/ha)	(kg/tree)	(kg/tree	(kg/ha)
A	464	0.357	0.562	0.799	1.602	3.320	1540	0.580	3.900	1810
(0-3 cm)		(0.01)	(0.04)	(0.03)	(0.20)	(0.25)	–	(0.06)	((0.30)	–
		*59.88	*45.44	*39.24	*35.01	–	–	*42.00	–	–
B	983	0.452	0.726	1.199	2.059	4.436	4.361	0.785	5.221	5132
(3-5 cm)		(0.04)	(0.07)	(0.13)	(0.21)	(0.44)	–	(0.04)	(0.46)	–
		*60.00	*46.22	*39.13	*35.05	–	–	*41.85	–	–
C	522	0.679	1.118	2.092	4.557	8.446	4406	1.184	9.630	5027
(5-7 cm)		(0.06)	(0.07)	(0.02)	(0.26)	(0.41)	–	(0.14)	(0.54)	–
		*60.05	*45.98	*39.00	*35.05	–	–	*41.09	–	–

Values in parenthesis are standard deviations
* moisture content

metres spacing in a one-hectare plot (2,500 seedlings) during June 1992. The transplanted seedlings were adequately irrigated twice a day, once at 8 a.m. and the second time at 4 p.m. until the soil was saturated. Irrigation was done for six months. Thereafter, no irrigation was done. Nearly 80 per cent of the seedlings survived and grew well. Weeding was done as and when required. After three years, the productivity of the plantation was estimated.

Biomass Estimation

The height and diameter at breast height (DBH) of all the trees in the plot was measured. The trees were classified according to their diameter: class A, 464 trees (dia. 0-3 cm), class B, 983 trees (dia. 3-5 cm) and class C, 522 trees (dia. 5-7 cm). Biomass studies were conducted using the stratified tree technique of tree harvesting (Negi *et al*, 1984). In each diameter class, six sample trees were randomly felled, sub-divided into leaves (phyllodes), twigs, branches and main bole. In order to estimate root biomass, a pit was dug around the tree with care taken to excavate the entire root of each tree. After excavation, the roots were washed with water to free the soil from the roots. Fresh weights of the components were taken in the field and sub-samples from each component were transported to the laboratory in plastic bags. These were oven-dried at 103 ± 2° C to a constant weight (Chaturvedi, 1984). The oven-dried weight of the samples was used to calculate the total standing biomass (kg/ha) of each diameter class.

RESULTS AND DISCUSSION

This is an even-aged plantation raised under fairly uniform conditions with no other associated trees either in the tree canopy or as undergrowth. However, there is a wide variation in the growth of the trees even within the same plantation. The difference in the growth pattern of even-aged plantations may be due to ecological or chance factors favouring certain seedlings in the initial stages so that they grow rapidly during the early years to attain a more favourable position which may, in turn, influence the tree form and site characters (Ovington and Madgwick, 1959). The diameter of the trees in this plantation ranged from 1-7 cm. The sampled trees show that the highest diameter class is generally more than twice the diameter compared to the lowest diameter class. The moisture content was highest in leaves (60 per cent), followed by twigs (46 per cent), roots (42 per cent), branches (39 per cent) and minimum in the main bole (35 per cent) which is presented in Table 1.

As expected, trees in the high diameter class had the highest biomass. The total biomass varied from 1,810 kg/ha (class A) to 5,132 kg/ha (class B) and 5,027 kg/ha (class C). The contribution of aboveground biomass varied from 84 to 86 per cent. The root biomass varied from 14 to 16 per cent which corroborates the studies in *Pinus patula* (Pinyopusarek, 1989) and *Eucalyptus globulus* (Negi and Sharma, 1984) plantations.

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BIOMASS PRODUCTION AND NUTRIENT DISTRIBUTION IN *LEUCAENA LEUCOCEPHALA* PLANTATIONS

P. SHANMUGHAVEL, K. FRANCIS AND ZHENG ZHENG

PRODUCTION by a plant community is a reflection of its capacity to assimilate solar energy. Under the same set of environmental conditions, different plant communities have different rates of biomass production based on their efficiency. The energy crisis and escalating wood prices have brought forest productivity under focus (Khan and Pathak, 1994). In the past, timber production has been the criterion of management; therefore, the rate of volume increment was considered adequate to assess the rate of annual production. Biomass production can be much more easily assessed in even-aged pure crops (Shanmughavel and Francis, 1995).

India has 158 million hectares area under different types of wastelands. Of the 75 million hectares of land with the Forest Department, about 40 million hectares are degraded. At present, only about 35.77 million hectare area is under closed forests. To meet the demand for firewood, forage, timber and pulp, the Government has set up the National Wasteland Development Board to undertake a massive programme of afforestation and tree plantation in wastelands (Dalal, 1992).

Among the large number of exotics tested so far, *Leucaena leucocephala* has proved to be the most versatile species due to its high adaptability to various edaphic and climatic conditions. It has been introduced in many countries for its potential to produce firewood and nutritious green forage on a very short rotation (Maslekar, 1964; Pathak *et al*, 1974; Pathak *et al*, 1981). But there is little on biomass production and nutrient distribution in biomass components. While estimating the biomass production of short rotation woodlands, the nutrients immobilised in the crop, and those removed permanently from the site by harvesting are of much concern and cannot be ignored. It is necessary to ascertain the total amount of nutrients immobilised in the crop and the distribution between various tree components to determine nutrients removed from the site.

The aim of the present study is to obtain information on biomass production, its distribution

among various tree components, the distribution among component plant parts and the effect of whole tree harvesting on these ecosystems of the site.

MATERIALS AND METHODS

Study Site

The study site is located at Bharathiar University, Coimbatore, longitude 76° 93' E and latitude 11° 1' N and 410 metres above mean sea level. A seven-year old plantation of *Leucaena leucocephala* was selected for the study. The climate of the area is monsoonic. The mean annual temperature and rainfall are 31.5° C and 120 mm, respectively. The study area has red soil. Soil pH was between 7-8. Electrical conductivity was 0.2 MS cm^{-1}. The mean soil nitrogen, phosphorus and potassium were 98, 7.6 and 115 kg/ha^{-1}, respectively.

Leucaena leucocephala (Lam.) de Wit.

Leucaena leucocephala, a species of the family Leguminosae, can form a mutually beneficial partnership with soil bacterium of the genus Rhizobium. It is an evergreen; however, in high winds, frost or prolonged drought, its compound leaves shed their dozens of tiny leaflets. Both leaves and leaflets fold up in response to moisture stress, cold temperature or darkness. *Leucaena's* tiny flowers form white, fluffy balls. They are usually self-pollinated and the flower heads produce drooping clusters of their flat, almost straight pods. Seed viability is high and the seeds can be successfully planted by hand or by machine. Plantations of *Leucaena leucocephala* are considered to be a promising solution to the problems of firewood and green fodder shortage in many developing countries. Annual increments of 30-40 m^3 ha^{-1} are expected under favourable conditions (Anonymous, 1980), although a lower annual increment of about 15 m^3 ha^{-1} has been reported from studies in north-central India (Chaturvedi, 1983).

Biomass Estimation

All the standing trees in the study site were divided into three diameter classes (A, B. and C). A total number of 12 trees, four from each diameter class, were felled randomly to ascertain above-ground biomass. After felling, each tree was sub-divided into bole, bark, leaf and twig and branches. Fresh weights of all the components were determined in the field. To estimate below-ground biomass, roots of all trees were excavated by making a trench around the tree. Representative samples of all plant parts were oven-dried at 80° C for 48 hours to obtain their oven-dry weight.

Estimation of Nutrients

Nitrogen and phosphorus were estimated as described by Armstrong (1967) using the Technicon Auto Analyser II (Gedko International, U. K.). The samples were digested in a Kjeidatherm digestion system KT 408 (Bonn) at 400 ° C for three hours. One-gram samples were digested in digestion tubes with both 2.5 g potassium sulphate and 5 m H_2SO_4. After digestion and cooling, the digested samples were made up to 50 ml with distilled water and used for analysis of N and P. The nutrients K, Ca and Mg were analysed using an atomic adsorption spectrophotometer (Perkin-Elmer 5000, U. S. A.) after wet digestion of 1 g sample with triple acid mixline (10 ml conc. HNO_3, 4 ml $HClO_4$ and 1 ml conc. Hill). The digested samples were filtered through Whatman No. 42 filter paper and made up to 100 ml with distilled water. This solution was stored and used for analysis (14). All analyses were performed on the average of three replicates.

TABLE 1
Range of Diameter Class and Sample Tree Parameters of 7-year-old *Leucaena leucocephala*

Age (Yrs)	Diameter (Class)	Range (cm)	Total No. of Trees	D.B.H. (cm)	Height (m)
7	A	2-3	160	2.5	3.0
	B	4-5	153	4.5	5.5
	C	5 and above	151	6.0	7.0

TABLE 2
Oven-Dry Weight of Components of 7-year-old *Leucaena leucocephala* (kg/tree)

Age (Yrs)	Diameter Class (cm)	Bole	Bark	Leaf + Twig	Branch	Total Above-Ground Biomass	Root	Grand Total Biomass
7	A	0.58	0.64	0.81	0.80	2.84	1.84	14.68
		0.43	0.57	0.71	0.88	2.59	1.74	4.33
		0.51	0.63	0.81	0.97	2.92	1.30	4.22
		0.50	0.59	0.49	0.67	2.25	1.68	3.93
	Average	0.50 (12.0)	0.60 (14.0)	0.70 (17.0)	0.83 (19.0)	2.65	1.64 (38.0)	4.29
	B	2.16	0.71	1.16	2.14	6.17	1.95	8.12
		1.90	0.78	1.25	2.32	6.25	1.71	7.96
		1.81	0.68	1.10	2.10	5.69	1.80	7.49
		1.70	0.72	1.15	2.40	5.97	1.89	7.86
	Average	1.89 (24.0)	0.72 (9.0)	1.16 (15.0)	2.24 (29.0)	6.02	1.83 (23.0)	7.85
	C	7.15	0.87	2.83	3.64	14.49	2.24	16.73
		6.85	0.90	2.11	3.10	12.96	2.10	15.06
		7.10	0.88	2.30	3.25	13.53	2.26	15.79
		5.90	0.77	2.43	3.30	12.40	1.90	14.30
	Average	6.75 (44.0)	0.85 (7.0)	2.41 (14.0)	3.31 (21.0)	13.34	2.12 (14.0)	15.47

Since there was no statistically significant differences ($P < 0.05$) observed in the production of biomass of each component, hence value expressed is the mean of three independent experiments. The values given in parenthesis are per cent contribution of biomass of each component.

TABLE 3
Total Standing Biomass of 7-Year-Old *Leucaena leucocephala* (Dm/tree)

Diameter Class	Bole	Bark	Leaf + Twig	Branch	Total Above-Ground Biomass	Root	Grand Total Biomass
A	80.96	97.12	112.9	132.9	424.0	262.4	686.4
B	289.4	110.4	178.3	343.7	921.0	281.0	1202.1
C	1019.2	129.1	364.9	496.5	2009.8	320.8	2360.6

Since there is no statistically significant differences ($P < 0.05$) observed in the production of biomass of each component, the value expressed is the mean of three independent experiments.

The biomass accumulation was found in the order of root>branch>leaf>twig>bark>bole (class A), branch>bole>root>leaf>bark (class B) and bole>branch>leaf>twig>root>bark (class C).

RESULTS AND DISCUSSION

Individual Tree Dimensions

These are even-aged plantations raised under similar edaphic and climatic conditions, with no associates either in the tree canopy as undergrowth, except for some annuals and grasses. However, there is a wide variation in the growth of trees even within the same plantation (Table 1). Within this particular plantation, the biggest tree was five times greater in diameter at breast height than the smallest tree. Similarly, the tallest tree was twice as tall as the shortest tree. This variation can be attributed to factors like genetics and site factors (George, 1977). A large variation in girth of trees was also observed (Khan and Pathak, 1994; Maslekar, 1994) in an even-aged plantation of *Leucaena leucocephala*.

Biomass Production

The oven-dry matter (kg/tree) of individual components of sample trees is tabulated in Table 2. The dry weight of all the above-ground components (bole, bark, leaf, twig and branch) and below-ground components increased with increasing diameter.

In general, the biomass of all the components increases with the increase in diameter and height, but the percentage contribution of various components to the above-ground biomass does not follow a trend. However, the percentage biomass of twig and leaf components decreases as diameter and height increase. No definite trend was observed in the case of branches. A steady increase in the contribution of below-ground biomass to the grand total biomass was also observed. Similar observation was reported on *Leucaena leucocephala* (Khan and Pathak, 1994; Maslekar, 1984; Pandey *et al*, 1981).

The sample tree data presented in Table 2 was used to calculate the total biomass per hectare at different diameter classes (Table 3). The above-ground biomass increases from lower diameter classes to higher diameter classes as was also observed in the case of below-ground biomass. The biomass of *Leucaena leucocephala* reported at 5.9 DM kg/tree and 23.8 DM kg/ha at the age of 3 and 4 years, respectively (Pandey *et al*, 1989) and the average biomass of 37.3 kg/tree was recorded

TABLE 4

Average Nutrient Contents of Sample Tree Components Year-7 *Leucaena leucocephala* (kg/tree)

Biomass Components	Diameter Class														
	A					B					C				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Bole	0.26	0.02	0.12	0.13	0.10	0.25	0.02	0.11	0.12	0.11	0.26	0.02	0.14	0.13	0.13
Bark	1.03	0.05	0.51	1.60	0.13	0.98	0.05	0.50	1.50	0.14	0.99	0.04	0.55	1.58	0.15
Leaf+Twig	2.00	0.10	1.50	0.75	0.38	1.95	0.10	1.45	0.77	0.38	1.90	0.09	1.59	0.77	0.39
Branch	0.55	0.03	0.39	0.38	0.06	0.53	0.03	0.04	0.40	0.06	0.57	0.03	0.40	0.38	0.07
Root	0.09	0.06	0.32	0.30	0.13	0.09	0.06	0.34	0.32	0.12	0.10	0.07	0.34	0.30	0.13

Since there were no statistically significant differences ($P<0.05$) observed in the average nutrient contents of sample tree components, values expressed are the mean of three independent experiments.

TABLE 5

Nutrient Retained in the Biomass Components of 7-Year-Old *Leucaena leucocephala* (kg/tree)

Biomass Components	Diameter Class														
	A					B					C				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Bole	21.00	1.61	9.71	9.67	8.09	72.36	5.78	31.84	34.73	31.84	265.0	20.30	142.69	132.50	132.50
Bark	100.30	4.85	49.53	155.39	12.62	108.25	110.50	55.20	111.90	15.46	127.8	5.16	129.65	203.90	19.36
Leaf+Twig	225.90	11.29	169.40	84.72	42.92	374.80	17.38	258.60	137.30	67.78	693.4	32.84	580.28	281.00	142.30
Branch	73.12	3.38	51.85	50.52	7.97	181.60	10.28	137.08	137.08	20.56	283.0	14.89	198.60	186.60	34.76
Root	23.61	15.74	93.96	78.72	34.11	25.29	16.86	95.56	89.93	16.86	32.0	22.46	109.09	96.26	41.71

Since there were no statistically significant differences ($P<0.05$) observed in the nutrient retained in the biomass components. values expressed are the mean of three independent experiments.

(Pandey and Singh, 1981) for this species at the age of five years. This is 10 per cent higher than that reported in the present study.

Concentration of Nutrients

The average nutrient concentration as a percent of oven-dry weight in different tree components is given in Table 4. The per cent composition of various nutrients varies. The highest concentrations are generally observed in leaves and twigs, followed by bark, branch, bole and root. The relative proportion of nutrient elements in leaf twigs and branches is N>K>Ca>Mg>P, in bole, N>Ca>K>Mg>P in bark, Ca>N>K>Mg>P and in root K>Ca>Mg>N>P in all diameter classes. These results agree with those reported earlier for *Eucalyptus hybrid* plantations (George, 1977), *Eucalyptus grandis* (Turner *et al*, 1983) and *Leucaena leucocephala* (Pandey *et al*, 1989).

Retention of Nutrients

The total nutrient content (kg/ha) in biomass components are tabulated in Table 5. The nutrient contents of the standing crops differ substantially in various forest types according to the degree of uptake and crop biomass which, in turn, are affected by tree age and the site quality even within the same species. The increase in nutrient content of the standing crop with stand age has a direct bearing on the total biomass of a forest stand (Ovington, 1962; Roddin and Bazilevisch, 1967). As such, the nutrient content accumulated varies considerably. In our study, the major portion of nutrients are accumulated in the order of root>branch>leaf>twig>bark>bole (2-3 cm DBH class), branches>bole>root>leaf>twig>bark (4-5 cm DBH class) and bole>branch>leaf>twig>root > bark (>5 cm DBH class). The results of the present study were in agreement with the earlier reports (Shanmughavel and Francis, 1995; George, 1977; Pandey *et al*, 1989; Rennie, 1955; Switzer and Nelson, 1972).

CONCLUSION

Rennie (1955) first drew attention to the amount of nutrients immobilised in the crop and questioned the capacity of poorer soils to supply, over prolonged periods, the nutrients required to maintain continuous timber production. The present data show that a large quantity of nutrients are tied up in the aerial parts of the trees. Switzer and Nelson (1972) have suggested that some advantage could be gained over several rotations by leaving foliage on the site, either by harvesting during the dormant season or by defoliating trees during the growing season. Plantations of *Leucaena leucocephala* are considered to be a promising solution to the problem of firewood and green fodder in many developing countries (Anonymous, 1980). The present data indicates that harvesting of *Leucaena leucocephala* leads to drain of nutrients from the site. Therefore, some safeguards, including supplemented fertilisation, etc. have to be taken while raising plantations of these species in order to protect the site from exhaustion.

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Floristic structure and biomass distribution of a tropical seasonal rain forest in Xishuangbanna, southwest China

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Abstract

The aim of this research was to study the forest community structure, tree species diversity and biomass production of a tropical seasonal rain forest in Xishuangbanna, southwest China. The community structure showed a diversified species composition and supported many species of economic significance. This tropical rain forest is closely related to *Malaysian* forests. The biomass and its distribution were studied using standard regression analysis and the clear-cut method for shrubs and herbs. The total biomass was 360.9 t/ha and its allocation in different layers was: tree layer 352.5 t/ha, shrub layer 4.7 t/ha, liana 3.1 t/ha and herb layer 0.5 t/ha. Most of the biomass was concentrated in the trees: stem 241.2 t/ha, root 69.6 t/ha, branch 37.2 t/ha and leaves 4.3 t/ha; The DBH class allocation of the tree biomass was concentrated in the middle DBH class. The biomass of six DBH classes from 20 to 80 cm was 255.4 t/ha. There are twenty-six species with biomass over 0.5% of the total biomass of the tree layer, and three species with biomass over 5%, i.e., *Pometia tomentosa*, *Barringtonia macrostachya* (5.4%) and *Terminalia myriocarpa* (5.2%). Data on stem, branch, leaves and root of the individual tree species were used to develop regression models. D^2H was found to be the best estimator of the biomass in this tropical rain forest.

However, higher biomass figures have been reported from tropical forests elsewhere e.g., 415–520 t/ha in the tropical forests of Cambodia, the tropical moist mixed dipterocarp forests, and the tropical moist logged moist evergreen-high, medium, and low yield forests of SriLanka. In some forests, lower accumulation of biomass was reported, e.g., 10–295 t/ha in the tropical moist forests of Bangladesh, the tropical moist dense forest of Cambodia, the tropical dry forests of India, the tropical moist forests of Penninsular-Malaysia, the tropical moist mixed dipterocarps forests of Sarawak-Malaysia, the tropical evergreen forests of Myanmar and the tropical moist ever-green logged forests of SriLanka. © 2001 Published by Elsevier Science Ltd.

Keywords: Tropical seasonal rain forests; Forest community structure; Tree species diversity; Biomass production; Biomass allocation and biomass tables

1. Introduction

Xishuangbanna is famous in China for its diverse flora, fauna and beautiful landscape. It is estimated that about 5000 species of higher plants (16% of those in China) exist in this area of 19,200 km^2 (0.2% of that in China) [1], of which nearly 1000 species of wild plants can be directly utilized by the people. This area has one of the greatest diversities of species in China and is of great importance in the maintenance

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of regional biodiversity. In the early 1950s, about 60% of the total area of Xishuangbanna was covered by forest. Recent investigation has revealed that this has declined greatly due to the rapid expansion of the local population and irrational exploitation of local forest resources. About 600,000 ha of natural forest have been lost during the last 30 years and the local forest cover has declined to 27% at the beginning of 1990s.

Deforestation in Xishuangbanna has led to ecological problems in the local environment and agricultural development [1] and also threatened the local species diversity. Until now, 340 plant species have been recognized as endangered, including 30 relict species, 150 regional endemic species, 130 rare species and 20 species of wild relatives of cultivated plants [2]. About 53 species have been officially listed as rare and endangered and are under explicit protection [3], most inhabit natural forests.

The continuous land pressure and vegetation degradation in the tropical forests have awakened interest in the study of forest tree species diversity and their biomass production. Assessing the total above ground biomass, defined as biomass when expressed as dry weight per unit area, is a useful way of quantifying the amount of resource available for traditional uses, either total biomass or by a component (eg. leaves, branches, and bole). The biomass of each forest component varies with the forest type [4].

The aboveground biomass of some tropical forests has been reported by several workers [5–14]. A survey of the literature reveals that work on the above ground biomass in Xishuangbanna is meagre with almost nothing reported systematically concerning the recent tree species diversity and its above ground production.

The main objectives of this investigation were to assess the diversity of the tree species and to estimate the biomass production and its allocation to above ground components.

2. Materials and methods

2.1. Physical geography

Xishuangbanna, southwestern China, borders Laos and Myanmar (21°09′–22°33′N, 99°58′–101°50′E) (Fig. 1). Owing to the southward inclination of the Nu and Wuliang Mountains in the north and their eastward and westward extension, the terrain slopes from north to south. The Lancang River with more than 20 tributaries, the upper course of the Mekong, flows through this area, resulting in many river valleys or small basins.

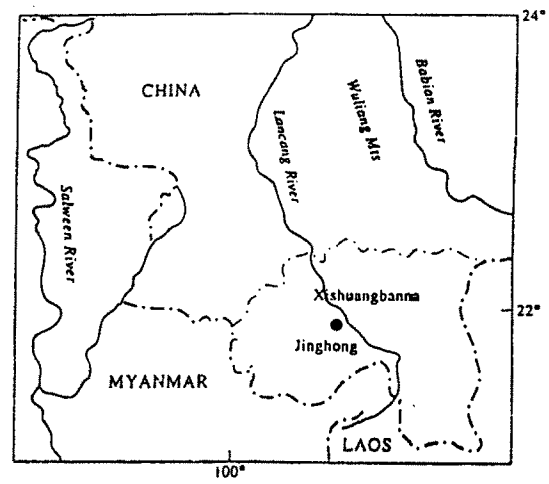

Fig. 1. Geographic location of Xishuangbanna.

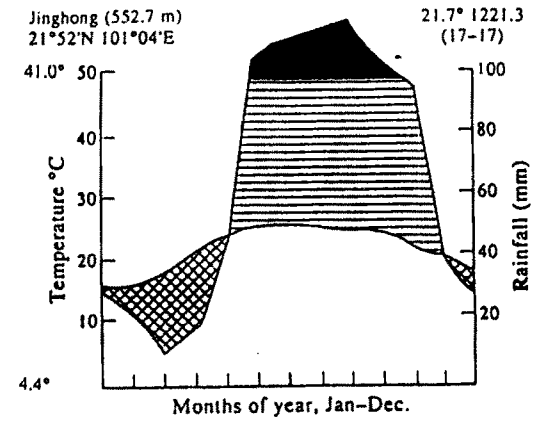

Fig. 2. Climatic diagram of Jinghong County (21°52′N, 101°04′E). ⊠, dry season; ▤, rainy season; ■, period with monthly rainfall over 100 mm.

The climate of Xishuangbanna is dominated by the southwest monsoon with high rainfall from November to April, so that there is a well defined alternation of rainy and dry seasons. Fig. 2 shows the climatic

diagram of Jinghong county (21°52′N, 101°04′E), the capital of Xishuangbanna. The annual mean temperature is 21.7°C, the mean temperature of the coldest month (January) is 15.5°C; annual precipitation is 1221 mm, but 1056 mm of it (more than 85%) occurs in the rainy season; the minimum monthly rainfall is 9.4 mm (February).

2.2. Study site

Xishuangbanna is on the northernmost edge of tropical Asia, where the tropical and temperate floras intermingle. This leads to an ecological mosaic of tropical vegetation represented by rainforest and subtropical vegetation by evergreen broadleaved forest. However, the distribution of these forests is not continuous because of the mountainous topography.

This is the most luxuriant forest in Xishuangbanna and is mainly distributed in the wet valleys, usually with small streams or on the low hills and flats below 1000 m altitude. It is rich in species and has a complex forest canopy and structure. In a 1.04 ha plot, 125 tree species (DBH > 5 cm) were recorded [15]. The canopy is uneven and consists principally of mega phenerophytes over 40 cm, and in some communities trees such as *Shorea chinensis* with umbrella crowns emerge sparsely from the canopy up to 60 m in height. The canopy trees usually develop strong buttresses for example, *Shorea chinensis*, *Terminalia myriocarpa*, and *Pometia tomentosa*. *Ficus altissima* has aerial roots from the large branches. In the understorey, cauliflorous trees occur frequently such as *Baccaurea ramiflora*, *Ficus auriculata*, and *Saurauia* spp. Many species of algae, lichens, mosses and ferns as well as Araliaceae, Araceae, Piperaceae, Moraceae and Orchidaceae comprise the epiphytes and stranglers. The woody climbers are very common and include *Byttneria integrifolia*, *Gnetum montanum*, *Tetracera scandens* and *Tetrastigma planicaule*, some reaching the forest canopy. The profile diagram (100 × 10 m^2) of the tropical seasonal rain forest in Xishuangbanna is presented in Fig. 3.

2.3. Vegetation analysis

The tropical seasonal rain forests vegetation analysis was done using random quadrat methods [16]. The 1 ha study area was subdivided into 100 subplots (10 × 10 m^2 each) with corner posts. The standing vegetation of a unit was considered to be made up of trees, shrubs, and herbs. Identity, height, dbh and canopy diameter were recorded for all trees in the plots. Shrubs and herbs including grasses were also recorded by name, height and cover in subplots under the forest canopy or plots in herbaceous communities. The nomenclature of all the species in Xishuangbanna is according to Li [1] and were identified by the Xishuangbanna Tropical Botanical Garden and Department of Ethnobotany, Kunming Institute of Botany, The Chinese Academy of Sciences, Yunnan, China. The importance value of each tree species was calculated by the combination of relative density, relative dominance and relative frequency [17,18].

3. Biomass estimation

3.1. Complete harvest of shrub and herb layers

In view of the mountainous topography and the fragmented distribution of local vegetation, the plots used were of different sizes [18]. Eight plots of 10 m × 10 m were selected for the estimation of shrub biomass. The plants were harvested flush to the ground and separated into wood and leafy portion and their fresh weight recorded. A pit was dug out around the plant to estimate root biomass. Care was taken to excavate the entire root system of each sample. Plant samples were taken and dried to determine the dry weight. To determine herb biomass, 10 plots of 2 m × 2 m were laid out and the herbs uprooted. The material was separated into shoot and root portions and dried at 80°C to determine its dry weight [14].

3.2. Tree biomass

Field studies were conducted using the tree harvesting method of stratified tree technique for biomass estimation [19]. To get a clear picture of the tree species diversity in the Tropical seasonal rain forests, sample plots measuring from 0.10 to 0.25 ha were enumerated and tree height diameter at breast height (DBH), basal area and the diameter of the crown of the trees were recorded. In order to avoid bias, the crown diameter was measured twice, along two perpendicular axes

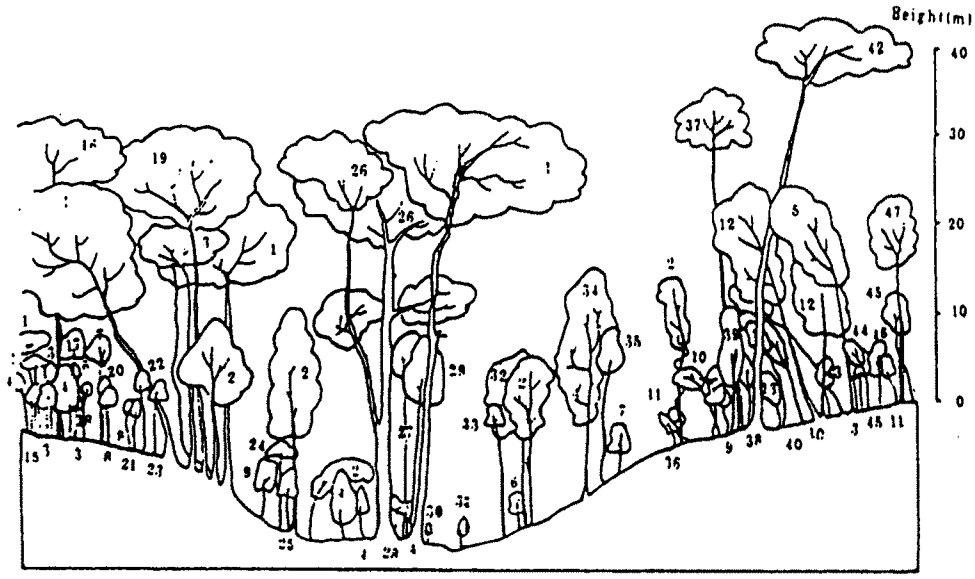

Fig. 3. Profile diagram (100 × 10 m²) of the seasonal rain forest in Xishuangbanna. Only tree ⩾ 5 cm DBH are included. Numbers for trees: 1. *Pometia tomentosa*; 2. *Barringtonia macrostachya*; 3. *Gironniera subaequalis*; 4. *Ardisia tenera*; 5. *Machilus rufipes*; 6. *Baccaurea ramiflora*; 7. *Lithocarpus leucostachyus*; 8. *Gomphandra tetrandra*; 9. *Mezzettiopsis creaghii*; 10. *Dichapetalum gelonioides*; 11. *Pittosporopsis kerrii*; 12. *Mitrephora calcarea*; 13. *Goniothalamus griffithii*; 14. *Turpinia cochinchinensis*; 15. *Randia acuminatissima*; 16. *Castanopsis ferox*; 17. *Amoora dasyclada*; 18. *Litsea liyuyingi*; 19. *Paramichelia baillonii*; 20. *Litsea panamonja*; 21. *Knema furfuracea*; 22. *Cinnamomum bejolghota*; 23. *Chisocheton siamensis*, 24. *Garcinia cowa*; 25. *Saprosma ternatum*; 26. *Terminalia myriocarpa*; 27. *Beilschmiedia* sp.; 28. *Syzygium polypetaloideum*; 29. *Picrasma javanica*; 30. *Drypetes* sp.; 31. *Sarcosperma kachinensis* var. *simondii*; 32. *Cleidion brevipetiolatum*; 33. *Cryptocarya acutifolia*; 34. *Barringtonia pendula*; 35. *Calophyllum smilesianum*; 36. ■; 37. *Semecarpus reticulata*; 38. *Pouteria grandifolia*; 39. *Lasiococca comberi* var. *pseudoverticillata*; 40. *Antiaris toxicaria*; 41. *Pseudavaria indochinensis*; 42. *Chukrasia tabularis* var. *velutina*; 43. *Actinodaphne henryi*; 44. *Millettia laptobotrya*; 45. *Nephelium chryseum*; 46. *Olea dioica*; 47. *Meliosma velutina*; 48. *Ficus langkokensis*.

(north–south and east–west). The average of these two measurements was considered to be the crown diameter [20]. The diameter range was divided into several diameter classes, depending upon the distribution of trees in each diameter class.

To estimate the dry weight of trees, 28 sample trees from 18 species representing the DBH classes from 5 to 150 cm were randomly selected. Fresh weight of all components (leaf, twig, branch, and pole) of sample trees were measured in the field. A pit was dug out around the tree to determine the root biomass. Care was taken to excavate the entire root system of each sample tree. Representative samples of all plant parts were oven dried at 80°C to obtain their oven dry weight.

The above ground oven dry weight of trees can be measured individually, but it is not realistic to do so for all inventories. Instead a practical solution is to develop regression equations based on data from the felled trees [20,21]. Such functions should use some easily measurable dimensions, e.g. diameter or height. In this study, the model $Y = a + bx$ was used, where Y is the above ground biomass in kg., x the D^2H and a, b the usual constants.

4. Results and discussion

4.1. Tree diversity

Out of the 730 individuals with DBH greater than 5 cm, 698 were identified to the species level, 25 to the genus level, 2 to the family level and 5 remained unidentified. The 32 trees, which could not be

Table 1
A comparison of tree density, basal area and tree height of Xishuangbanna seasonal rain forest with those of Sarawak lowland rain forests (DBH $\geqslant$ 10 cm)[a]

Forest type	Locality	Density (trees ha)	Basal area (m^2/ha)	Mean basal area (m^2/tree)	Mean height (m)
Seasonal rain forest	Xishuangbanna, China	386	30.03	0.078	18.6[b]
Alluvial forest	Sarawak, Malaysia	615	28	0.046	7.8
Dipterocarp forest	Sarawak, Malaysia	778	57	0.073	21.8

[a]Data of Sarawak lowland rain forests are from Proctor et al. (1983).
[b]17 snapped and prone trees are excluded.

Table 2
The ten families with the biggest importance values (IV) in the plot

Rank	Family	IV	Distribution
1	Sapindaceae	34.43	Trop.[a] and subtrop.
2	Euphorbiaceae	26.17	Trop.[a] subtrop and temp.
3	Lecythidaceae	23.19	Trop.[a]
4	Meliaceae	22.34	Trop.[a] and subtrop.
5	Lauraceae	20.99	Trop.[a], and subtrop.
6	Ulmaceae	16.94	Trop., subtrop and temp.
7	Anonaceae	12.52	Trop.[a] and subtrop temp.
8	Elaeocarpaceae	10.23	Trop.[a], subtrop and temp.
9	Myrsinaceae	9.15	Trop., subtrop and temp.
10	Myrtaceae	8.55	Trop. and subtrop.

[a]Where mainly distributed.

determined for the species level belonged to 18 different taxa. The total basal area was 31.28 m^2/ha indicating a mean basal area of 0.043 m^2/tree. The mean tree height was 13.02 m. Compared with Sarawak lowland rain forests [22], this forest has a very low density and poor species composition. Its basal area and mean tree height are lower than those of dipterocarp forests, but higher than those of alluvial forests; however, the mean basal area per tree is higher than both of them (Table 1).

The most important families and their distribution are given in Table 2. Of the 10 families observed, seven were from the tropics. It is clear that, at the level of genus, tropical Asian and pantropical elements are the major elements in the floral composition accounting for two thirds of the total genera (Fig. 4). About half of the first 25 most important species are also distributed in Malaysia (Table 3). *Pometia tomentosa* is distributed in the area ranging from India and the southern slopes of the Himalayas over continental SE Asia to Malaysia and extends to the Philippines and New Guinea, *Barringtonia macrostahya*

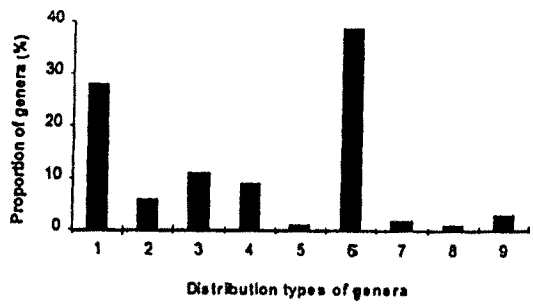

Fig. 4. Proportional composition of the genera in different distribution types. Definition for the distribution types following: Wu (1991). 1. Pantropic; 2. Trop. Asia & Trop. Amer. disjuncted; 3. Old World Tropics; 4. Trop. Asia & Trop. Australasia; 5. Trop. Asia to Trop. Africa; 6. Trop. Asia (Indo-Malaysia); 7. E. Asia & N. Amer. disjuncted; 8. Mediterranean, W. Asia to C. Asia; 9. E. Asia.

and *Gironiera subaequalis* occur in continental SE Asia and east Malaysia.

Li et al. [1] demarcated this area in the northernmost of the Indochinese region bordering in the

Table 3
The characteristics of the 25 tree species with the biggest importance values (IV)[a]

Name of species	Family	Total number of trees	Mean height (m)	Mean DBH (cm)	Mean BA (cm^2)	IV
Pometia tomentosa	Sapindaceae	38	25.6	38.3	1669	30.55
Barringtonia macrostacjya	Lecythidaceae	43	14.1	18.3	347	15.86
Gironiera subaequalis	Ulmaceae	45	13.2	15.0	238	15.26
Chisocheton siamensis	Meliace	30	10.4	11.7	162	9.76
Ardisia tenera	Myrsinaceae	33	6.6	9.5	80	9.15
Barringtonia pendula	Lecythidaceae	19	15.6	29.7	414	7.33
Millettia Laptobotrya	Papilionaceai	28	6.6	8.1	57	7.04
Messettiopsis creaghii	Annonaceae	23	10.3	12.7	165	7.04
Dichapetalum gelonioides	Dichapetalaceae	22	10.2	10.3	96	6.06
Terminalia	Combretaceae	1	42.0	148.7	17358	5.85
Garuga floribunda var. Gamblei	Burseraceae	8	22.0	30.4	1194	5.41
Sloanea cheliensis	Elaeocarpaceae	10	16.3	22.9	816	5.40
Pouteria grandifolia	Sapotaceae	10	14.2	19.9	669	5.09
Lithocarpus leucostachyus	Fagaceae	10	16.6	20.9	608	4.73
Garcinia cowa	Guttiferae	14	12.0	11.3	128	4.70
Syzygium polypetaloideum	Myrtaceae	16	8.7	11.1	111	4.66
Cleidion brevipetiolatum	Euphorbiaceae	11	11.3	18.0	426	4.26
Baccaurea ramiflora	Euphorbiaceae	11	8.6	13.0	165	3.83
Ficus langkokensis	Moraceae	12	10.2	10.7	100	3.77
Randia acuminatissima	Rubiaceae	13	6.1	7.1	41	3.53
Semecarpus reticulate	Anacardiacea	7	17.0	21.1	616	3.44
Chukrasis tabularis var. Velutina	Meliaceae	1	45.0	110.8	9637	3.38
Phoebe puwenesis	Laurceae	7	13.3	19.5	586	3.37
Elaeocarpus varunua	Elaeocarpaceae	4	30.5	38.2	1468	3.07
Elaeocarpus prunifolioides	Elaeocarpaceae	9	12.8	12.1	139	3.05

[a]Species also found in Malaysia.

Eastern Asiatic region, reflecting the interlacement of the flora from both the south and the north, whereas tropical seasonal rain forest is the northward extension of the tropical Asian rain forests in the everwet conditions, which mix with some deciduous trees here and form a unique rain forest. Evergreen broadleaved forest is the climatic climax of subtropical and temperate China, which extends southward into Xishuangbanna and occupies the mountain areas, where some tropical species mingle with the species from the north.

The traditional characteristics of the Xishuangbanna flora. Some workers [23–25] emphasized which naturally result in the vegetational mosaic of the tropics and subtropics in this area. The predominance of the tropical monsoon climate and the mountainous landforms which bring about the patchy distribution of the local plant communities, in addition, intensify the floral and vegetational mixture and emergence, representing one of the important features of the Xishuangbanna vegetation. The occurrence and the dominance of the tropical Asian element in the tree species composition of the seasonal rain forest—a climatic climax forest in Xishuangbanna suggest its intimate relationship to the paleotropical Indo-Malaysian rain forests. Of course, the expansion and compression in the distributional ranges of tropical plant species resulting from climatic fluctuations in the Pleistocene glacial and interglacial phases [26–28] led to the northward shifting of Malaysian flora through continental SE Asia. Some of them, as relict elements, inhabited some small refuges-low lands valley obstructed by large mountains in the north (e.g. the Himalayas). Others evolved into a new taxa. These events unavoidably created pronounced influences on the flora of local forests. Under such a complex geological background and

biogeographical history, the basic floral pattern of Xishuangbanna seasonal rain forest was established.

5. Biomass production

The determination of tree biomass in natural tropical and sub-tropical environments has always been compounded by the problem of the presence of a multitude of trees on which no information was available. Unlike production forestry, where in a limited number of tree species has been extensively studied in natural environments, the attempts to determine standing biomass of trees have been handled on a case by case basis.

The biomass production of this tropical rain forest is presented in Table 4. The total biomass of the forest community was 360.9 t/ha and its allocation in different layers was: tree layer 352.5 t/ha (accounts for 97.69%), shrub layer 4.7 t/ha (1.31%). Liana 3.1 t/ha (0.86%), and herb layer 0.5 t/ha (0.14%). Most of the biomass was concentrated in the tree layer. The biomass allocation in the tree layer was: stems 241.2 t/ha (68.4%), roots 69.6 t/ha (19.7%), branches 37.2 t/ha (10.5%) and leaves 4.3 t/ha (1.2%). The DBH allocation of the biomass was mainly concentrated in the middle DBH class, i.e. the biomass of six DBH classes from 20 to 80 cm reached 255.4 t/ha (72.4%) (Table 5).

Higher accumulation of forest biomass has been reported in some tropical forests of the World (Table 6). The total biomass is 348–415 t/ha in the tropical rain forests of Cambodia [8], 370 t/ha in the tropical moist semi-dense forests of Cambodia [29], 325–385 t/ha in the tropical moist mixed dipterocarps-dense stocking, flat to undulating terrain forests of Sarawak Malaysia [30], 370–520 t/ha in the tropical moist old growth dipterocarp forests and 300–370 t/ha in the tropical moist logged dipterocarp forests of Philippines [31], 370–520 in the tropical moist evergreen—high yield, 365–470 t/ha in the tropical moist evergreen—medium yield, 190–400 t/ha in the tropical moist evergreen low yield forests of SriLanka [32], 425–465 t/ha in the tropical rain forests of Abidjan, Ivory Coast [33], 505 t/ha in the Montane rain forests of New Guinea [12] and 458.2 t/ha in the tropical rain forests of Western Ghats, India [14].

Table 4
The biomass of the tropical wet seasonal rain forest (t hm^{-2})

Layers	Organs	Biomass	Percentage of total biomass (%)
Tree	Stems	241.270	66.85
	Branches	37.287	10.33
	Leaves	4.392	1.22
	Roots	69.614	19.29
	Total	352.563	97.69
	Shrubs	4.737	1.31
	Herbs	0.501	0.14
	Liana	3.108	0.86
	Total	360.909	100.00

Lower accumulation of biomass has been reported in other tropical forests to be 150–210 t/ha in the tropical moist closed large and small crown forests of Bangladesh [34], 85–190 t/ha in the tropical moist disturbed closed and open forests of Bangladesh [35], 162–206 t/ha in the tropical moist closed-large crown and small crowns of Bangladesh [35], 70–295 t/ha in the tropical moist dense forests of Cambodia [29], 16–81 t/ha in the tropical dry high to low volume closed forests of India [36], 185–275 t/ha in the tropical moist forest of Penninsular-Malaysia [37], 280–330 t/ha in the tropical moist mixed dipterocarps—dense stocking forests of Sarawak-Malaysia [37], 10–200 t/ha in the tropical evergreen forests of Myanmar [38], 225–280 t/ha in the tropical moist evergreen logged forests of SriLanka [32], 265.8 t/ha in the tropical rain forests of Khade, Ghana [5], 290.6 t/ha in the tropical rainforests of Khado Chang, Thailand [6] 262.9 t/ha in lower Montane forests of El Verde [9], 233.4 in the lower Montane forests of El Verde, Puerto Rico [10] 286 t/ha in the tropical rain forests of New Guinea [13], 229–312 t/ha in the Montane rain forests of Jamaica [39] and 230–290 t/ha in the tropical rain forests of Malaysia [11]. It is clear from this comparative account that there are large variations in the accumulation of biomass in different forest types. These variations may be attributed to the factors such as forest type, growing conditions, non-random sampling, within site variance, etc. [40,41].

6. Regression equations

Regression equations were produced when the need arose, resulting in many custom-made regressions.

Table 5
The allocation of the biomass among the different diameter classes for tree layers of the tropical wet seasonal rain forest (t hm^{-2})

DBH classes (cm)	No. of individual (n hm^2)	Stems	Branches	Leaves	Roots	Total	Percentage of tree biomass (%)
$5 \leqslant \sim < 10$	359	2.93	0.76	0.402	0.837	4.93	1.40
		59.43%	15.44%	8.15%	16.98%	100%	
$10 \leqslant \sim < 20$	182	12.914	3.400	0.784	4.179	21.241	6.02
		60.84%	16.01%	3.52%	19.67%	100%	
$20 \leqslant \sim < 30$	89	26.908	7.869	0.923	6.53	42.23	11.98
		63.72%	16.27%	2.19%	17.83%	100%	
$30 \leqslant \sim < 40$	41	27.452	5.757	0.618	7.151	40.978	11.62
		66.99%	14.05%	1.51%	17.45%	100%	
$40 \leqslant \sim < 50$	20	26.040	4.139	0.414	7.197	37.79	10.72
		68.91%	10.95%	1.10%	19.04%	100%	
$50 \leqslant \sim < 60$	13	26.598	3.506	0.335	7.651	38.09	10.8
		69.83%	9.20%	0.88%	20.09%	100%	
$60 \leqslant \sim < 70$	12	36.817	4.099	0.375	10.979	52.27	14.83
		70.44%	7.84%	0.72%	21%	100%	
$70 \leqslant \sim < 80$	8	31.181	3.141	0.28	9.5	44.102	12.51
		70.70%	7.12%	0.64%	21.54%	100%	
$80 \leqslant \sim < 90$	2	10.739	0.947	0.082	3.367	15.135	4.29
		70.95%	6.26%	0.54%	22.25%	100%	
$90 \leqslant \sim < 100$	1	5.93	0.501	0.043	1.876	8.35	2.73
		71.20%	6.00%	0.51%	22.47%	100%	
$100 \leqslant \sim < 110$	1	8.836	0.632	0.051	2.897	12.416	3.52
		71.17%	5.09%	0.41%	23.33%	100%	
$110 \leqslant \sim < 120$	1	9.606	0.664	0.054	3.174	13.501	3.83
		71.17%	4.92%	0.40%	23.51%	100%	
$140 \leqslant \sim < 150$	1	15.316	0.871	0.067	5.276	21.53	6.11
		71.14%	4.05%	0.31%	24.51%	100%	
Total	730	241.27	37.287	4.392	69.614	352.563	100
		68.43%	10.57%	1.25%	19.75%	100%	

Biomass regressions were made against stem diameter [42] stem circumference [43,44], stem basal area [45,46], tree crown dimensions [47] and combinations of tree crown and stem dimensions [48] diameter and height [49] and diameter [50].

The present study shows that in the regression of square of diameter and height against weight, there is a great similarity between the regression lines of a range of trees in Xishuangbanna. This similarity allows the determination of tree biomass in a normal diverse forest with the replacement of the regression lines of the individual tree species linking square of diameter and height with biomass by one combi-line. The regression models of the tree and liana biomass of tropical seasonal rain forests of Xishuangbanna are presented in Table 7. In the tree layer of all DBH classes, the correlation coefficient was found to be 99% of confidence limits, for stems, branches, and roots, and for leaves it was 95% of confidence limit.

These regression equations can be used to carry out extensive non-destructive surveys of tree standing biomass. This will be very important in determining the effect of harvesting the wood, in establishing tree stocks and mean annual increments, and in assisting the interpretation of remote sensing data. By its nature, the effects of harvesting wood are patchy and normally of a scale for which satellite imagery is too large. In addition, tree population data are also obtained. The importance of this is that, in an early stage, the influence of harvesting wood on the population structure of a forest or woodland is often much more marked than the decrease of standing biomass [51,52]. Therefore, these types of works have the advantage of giving an early warning of the long term effects of harvesting

Table 6
Biomass distribution of tropical forests in the Asian countries

Country	Forest type	General climate	Above ground Biomass (t/ha)
Bangladesh	Closed-large crowns	Moist	210
	Closed-small crowns	Moist	150
	Disturbed closed	Moist	190
	Disturbed open	Moist	85
Bangladesh	Closed-large crowns	Moist	206
	Closed-small crowns	Moist	162
Cambodia	Dense	Moist	295
	Semi-dense	Moist	370
	Secondary	Moist	190
	Open	Moist	160
	Open	Dry	70
Cambodia	Well to poorly stocked Evergreen	Moist	100–155
	deciduous	Moist	120
India	High to low volume		
	closed	Dry	44–81
	Forest fallow	Dry	16
Malaysia-Peninsular	Superior to moderate-hill	Moist	245–310
(National)	Poor hill	Moist	
	Upper hill	Moist	275
	Disturbed hill	Moist	200
	Logged hill	Moist	180
	Forest fallow	Moist	140
	Freshwater swamp	Moist	220
	Disturbed freshwater	Moist	285
	Swamp		
	Logged freshwater		
	Swamp	Moist	185
Malaysia-Sarawak	Mixed dipterocarps-		
	dense	Moist	325–385
	Stocking, flat to		
	Undulating terrain		
	Mixed dipterocarps-		
	Dense	Moist	330–405
	Stocking, mountainous		
	Mixed dipterocarps-	Moist	280–330
	Medium stocking, flat to		
	Mountainous		
Myanmar	Evergreen		60–200
	Mixed deciduous		45–135
	Indaing forest		10–65
Philippines	Old-growth dipterocarp	Moist	370–520
	Logged dipterocarp	Moist	300–370
Sri Lanka	Evergreen-high yield	Moist	435–530
	Evergreen-medium yield	Moist	365–470
	Everygreen-low yield	Moist	190–400
	Evergreen-logged	Moist	255
	Secondary	Moist	280

Table 7
The regression models of the tree and liana biomass of the tropical wet seasonal rain forest

Layers	DBH classes	Organs	Regression models	Correlation coefficients (r)
Tree	$5\ cm \leqslant D \leqslant 20\ cm$	Stems	$W_s = 0.0296\ (D^2H)^{0.9539}$	0.9861[b]
		Branches	$W_b = 0.0158\ (D^2H)^{0.8285}$	0.8430[b]
		Leaves	$W_l = 0.0188\ (D^2H)^{0.5027}$	0.6596[a]
		Roots	$W_r = 0.0112\ (D^2H)^{0.9045}$	0.9535[b]
		Total	$W_t = 0.0675\ (D^2H)^{0.9040}$	0.9790[b]
	$20\ cm < D \leqslant 150\ cm$	Stems	$W_s = 0.0606\ (D^2H)^{0.8976}$	0.9797[b]
		Branches	$W_b = 0.5962\ (D^2H)^{0.5226}$	0.8661[b]
		Leaves	$W_l = 0.1707\ (D^2H)^{0.4280}$	0.8336[a]
		Roots	$W_r = 0.0069\ (D^2H)^{0.9781}$	0.9555[b]
		Total	$W_t = 0.1341\ (D^2H)^{0.8599}$	0.9758[b]
Liana	$2\ cm < D \leqslant 13.8\ cm$	All	$W_t = 0.0740\ (D^2H)^{0.8495}$	0.9756[b]

[a] $P < 0.01$.
[b] $P < 0.001$.

wood on the forest or woodland and the possibility of design woodland management systems to avoid the adverse effects of harvesting wood [53,54].

Acknowledgements

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Nutrient cycling in a tropical seasonal rain forest of Xishuangbanna, Southwest China. Part 1: tree species: nutrient distribution and uptake

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Abstract

Tropical rain forests are characterized by large numbers of the species with diverse growth habits. The objective of the present study was to determine the distribution of nutrient content in the major trees of the tropical rain forests in Xishuangbanna. This will improve the understanding of the nutrient losses from such sites that result from harvesting and flow of nutrients within the ecosystem and lead to the development of effective and rational forest management strategies. Based on the results in this study, the distribution of nutrients among biomass components of trees varied: The ordering of major elements concentrations was K > N > Mg > Ca > P in branch, stem and root tissues but was N > K > Mg > Ca > P in leaves. The maximum amount of all nutrients per ha occurred in the stems followed by branches, roots and leaves. Of the total uptake of 6167.7 kg ha^{-1} of all nutrients, the contribution of various nutrients was found to be N (2010.6 t ha^{-1}), P (196.3 t ha^{-1}), K (2123.8 kg ha^{-1}), Ca (832 kg ha^{-1}) and Mg (1005 kg ha^{-1}). However, comparing the nutrient uptake of other tropical and sub tropical forests, the results indicated that rates for the Xishuangbanna forests were 20–35% lower than previously reported values. © 2001 Published by Elsevier Science Ltd.

Keywords: Tropical rain forests; Tree species; Nutrient distribution; Nutrient uptake

1. Introduction

During the past decade there has been a marked shift away from considering the forests as production systems for wood, towards a realization that the total organic production is important. Increased demand for forest products, the search for renewable resources or raw materials, and an increased concern for the well being of forest ecosystems are combining to stimulate study of the total forest biomass and its nutrient dynamics (Madgwick et al., 1977). Study of the distribution of nutrients in biomass production systems is very essential (Grove and Malajucznk, 1985). Even in natural ecosystems the nutrient budgeting may be delicately balanced. Therefore, understanding of nutrient distribution in different biomass components of tree species in the tropical forests in terms of cycling through geochemical, biochemical and biogeochemical processes needs to be investigated (Forrest and Ovington, 1970; Bradstock, 1981; Turner, 1986). The relative contribution of this process can be studied by examining the soil litter systems, uptake of nutrients, distribution of nutrients in natural and plantation forest ecosystems. These studies are important in that they provide information on nutrient budgeting of ecosystems (Whitemore, 1975; Turner, 1986; Das and Ramakrishnan, 1987).

The species diversity, structural complexity and apparent luxuriant characteristics of tropical rain forests gives the impression that they occupy highly fertile soils. It is now recognized, however, that rain forest soils are of less-than-average fertility, which can be attributed to the very high rainfall and temperatures experienced in those areas (Fournier, 1978). These factors encourage the rapid breakdown and incorporation of organic matter derived from the forest itself, mostly in the form of leaf and litter-fall. The high rainfall means that many nutrients are leached out of the soil very quickly (Stark, 1971a). In response to this, the distribution of nutrients within a tropical rain forest is markedly different to that of other forest types. In most forests the majority of the nutrients accumulate in the soil (Westman and Rogers,

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1977; Miller, 1979). In a tropical rain forest a high proportion of the nutrients are found in the biomass, mostly in the bark and foliage (Stark, 1971a; Ruddle and Manshard, 1981), with an equal proportion occurring in the litter. This can be thought of as biomass, since it may never be incorporated into the soil but be acted on by mycorrhizal hyphae and the nutrients transferred directly back into the vegetation (Stark, 1971b).

The study of plant mineral nutrients in tropical rain forests ecosystem, both above and below ground, has been slow to develop (Hilton, 1987). There are practical problems in the assay of nutrients in the different components, leaves, twigs, wood and bark. The above ground biomass of primary lowland forests is usually 400 t ha^{-1} and a sophisticated system of subsampling must be devised to sample the considerable fraction of root biomass that is in the fine roots, which are very difficult to extract (Westman and Rogers, 1977; Jordan et al., 1981). Standard chemical methods of assaying soil nutrients are not directly applicable. However there are now enough studies, despite these difficulties for some conclusions to be reached (Vanclay, 1991, 1992).

Substantial information is available on nutrient content and cycling in temperate forests (Greenland and Kowal, 1960; Nye, 1961; Jordan and Kline, 1972). But relatively little is known about nutrient distribution and cycling in tropical and sub tropical forests (Golley et al., 1975; Grubb and Edwards, 1982; Hilton, 1987; Vanclay, 1992). Only minimal information has been published (Hilton, 1987; Prieston and Vanclay, 1988; Rai, 1984; Whitemore, 1975; Vanclay, 1991) on nutrient distribution and cycling in the tropical rain forests. However, no information is thus far available on nutrient distribution in biomass components and its cycling of tropical rain forests of Xishuangbanna, Southwest China. Therefore, the objective of the present study was to determine the distribution of nutrient content in the major trees of the tropical rain forests in Xishuangbanna, which will improve our understanding of the nutrient losses from such sites as a result of harvesting and flow of nutrients within the ecosystem, for development of effective and rational forest management strategies.

2. Methods

2.1. Location characteristics

Xishuangbanna, Southwestern China, borders Laos and Myanmar (21°9′–22°33′N, 99°58′–101°50′E) (Fig. 1). Owing to the southward inclination of the Nu and Wuliang Mountains in the north and their eastward and westward extension, the terrain slopes from north to south. The Lancang River, with more than 20 tributaries, the upper course of the Mekong flows through this area,

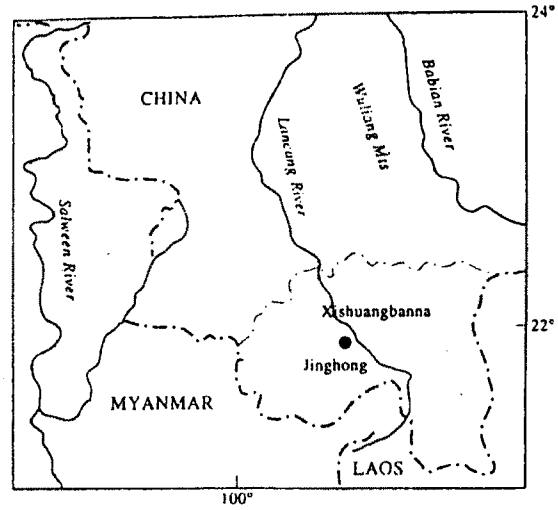

Fig. 1. Geographic location of Xishuangbanna.

resulting in many river valleys and small basins. The climate of Xishuangbanna is dominated by southwest monsoons with high rainfall occurring from November to April, so that there is a well defined alternation of rainy and dry seasons. A climatic diagram of Jinghong county (21°52′N, 101°04′E), the capital of Xishuangbanna is shown in Fig. 2. The annual mean temperature is 21.7°C, the mean temperature of the coldest month (January) is 15.5°C; annual precipitation is 1221 mm, but 1056 mm of it (more than 85%) occurs in the rainy season; the minimum monthly rainfall is 9.4 mm (February). The soil in the area was laterite, red to brown in colour and sandy loam in texture.

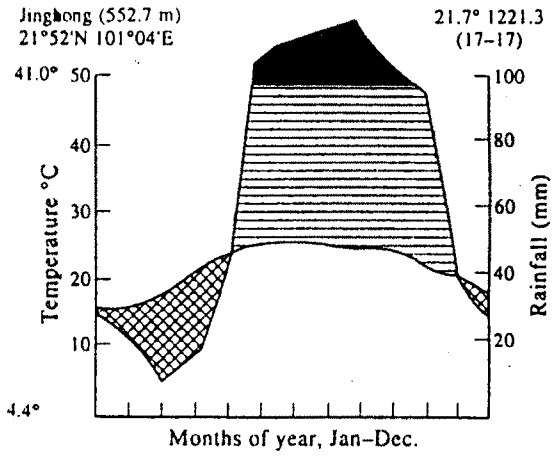

Fig. 2. Climatic diagram of Jinghong County (21°52′N, 101°04′E). (▤) dry season; (▤) rainy season; (■) period with monthly rainfall over 100 mm.

The soil moisture content was determined by drying 10 g fresh soil in a hot air oven at 150°C for 24 h. The pH was observed on a digital pH-meter (Systronics-121, India) in a 1:5 (w:v) soil water suspension. For N, P, K, determinations the samples were air dried and sieved (0.2 mm). Total N was estimated by the indophenol blue method described by Allen (1974). The molybdenum blue method of Jackson (1967) was followed to determine the available soil P, K was extracted from the soil in an ammonium acetate solution (pH = 7) and measured with a digital flame photometer (Systronics-121, India). To obtain total soil nutrient concentrations per ha. the percentage nutrient content was divided by 100 and the result multiplied by 2 million. (1 ha contains 2×10^6 kg soil, George and Varghese, 1990a.) The total soil concentrations of N, P, K, Ca and Mg were 4200, 410, 4000, 1900 and 2000 kg ha^{-1}, respectively.

2.2. Tree species composition

In latitude, Xishuangbanna is on the northern most edge of tropical Asia, where the tropical and temperate floras intermingle. This leads to an ecological mosaic of tropical vegetation represented by rain forest and subtropical vegetation by evergreen broad leaved forest species. However the distribution of forest plants is not continuous because of the mountainous topography. This is the most luxuriant forest in Xishuangbanna and is mainly distributed in the wet valleys, usually with small streams or on the low hills and flats below 1000 m of altitude. It is rich in species composition and has a complex forest canopy structure. In a hectare plot, 125 tree species diameter at breast height (DBH > 5 cm) were recorded (Zhu, 1992). The principle trees consist of the following: (1) *Pometia tomentosa*, (2) *Barringtonnia macrostachya*, (3) *Terminalia myriocarpa*, (4) *Gironniera subaequalis*, (5) *Claidion brevipetiolatum*, (6) *Mezzettiopsis creaghii*, (7) *Carcinia cowa* and (8) *Ardisia tenera*.

2.3. Biomass estimation

The experiment was conducted as a randomized complete block design with three replicates. The dimensions of the individual plots were 0.10×0.25 ha^2. Field studies were conducted using the tree harvesting method of stratified tree technique for biomass estimation (Art and Marks, 1971). To get a clear picture of the tree species diversity in the tropical seasonal rain forests sample plots measuring from 0.10 to 0.25 ha were established and the tree height, DBH, and basal area were recorded for each plot. The whole diameter range in the tree species were divided into several diameter classes, depending upon the distribution of trees in each diameter class. For estimation of dry weight of tree species 28 sample trees were randomly selected. Fresh weight of all components of trees were measured in the field by separating them into leaf, branch, pole and root. Representative samples of all trees were oven dried at 80°C to obtain their oven dry weight. The above ground oven dry weight of trees could be measured directly by felling them, oven drying all components and then weighing. However, it was not realistic to do this for all inventories. Instead a practical solution was to develop a regression equation based on data from felled trees where this was possible. Such functions provided easily measurable dimensions such as diameter or height. In this study we employed the following model of $Y = a + bX$, where Y is above ground biomass in kg, X is DBH and a, b are the usual constants.

2.4. Nutrient analysis

The wood was reduced to sawdust by means of an electrical saw. The sawdust was sieved initially with 65 meshes cm^2 and later with 200 meshes cm^2. The material retained during the second sieving was called "average wood" and was used for the analysis. The wood used for the analysis retained minimal moisture. Nitrogen and phosphorus were estimated as described by Armstrong et al. (1967) using a Technicon Autoanalyser 11 (Gedko International, Cheshire, UK). The sample was digested in a Kjeldatherm digestion system KT 408 (Bonn) at 400°C for 3 h. One gram samples were digested in digestion tubes with 2.5 g K_2SO_4 and 5 ml H_2SO_4. After digestion and cooling, the digested sample was made up to 50 ml with distilled water and used for analysis of N and P. The nutrients K, Ca and Mg were analyzed using an atomic adsorption spectrophotometer (Perkin–Elmer 5000, Miamisburg, Ohio, USA) after wet digestion of a 1 g sample with a triple acid mixture (10 ml conc. HNO_3, ml $HClO_4$ and 1 ml conc. HCl). The digested samples were filtered through Whatman No. 42 filter paper and made up to 100 ml with distilled water. This solution was stored and used for analysis (Issac and Johnson, 1975). All analyses was performed on three replicates and averages are presented.

2.5. Statistical analysis

Data on nutrient accumulation in tree components were subjected to analysis of variance (ANOVA) and means were separated using Duncans Multiple Range Test (DMRT) ($P < 0.05$) (IRRI STAT, 1993).

3. Results and discussion

3.1. Biomass

The production of biomass on an unit area basis is given in Table 1. The biomass measurements revealed that *Pometia tomentosa* had the most dry matter accumulation

Table 1
Production of biomass (dry-matter) on a unit area basis, (t ha^{-1})

Tree species	Leaves	Branches	Stems	Roots	Total
Pometia tomentosa	0.375	4.099	36.817	10.979	52.270
	(0.72%)[a]	(7.84%)	(70.44%)	(21.00%)	
Barringtonia macrostachya	0.280	3.141	31.181	9.500	44.102
	(0.64%)	(7.12%)	(70.70%)	(21.54%)	
Terminalia myriocarpa	0.784	3.400	12.914	4.179	21.241
	(3.52%)	(16.61%)	(60.84%)	(19.67%)	
Gironniera subaequalis	0.414	4.319	26.040	7.197	37.790
	(1.10%)	(10.95%)	(68.91%)	(19.04%)	
Cleidion brevipetiolatum	0.335	3.506	26.598	7.651	38.090
	(0.88%)	(9.2%)	(69.83%)	(20.09%)	
Mezzettiopsis creeghii	0.618	5.757	27.452	7.151	40.978
	(1.51%)	(14.05%)	(66.99%)	(17.45%)	
Carcinia cowa	0.923	7.869	26.968	6.530	42.230
	(2.19%)	(16.27%)	(63.72%)	(17.83%)	
Ardisia tenera	0.082	0.947	10.739	3.367	15.135
	(0.54%)	(6.26%)	(70.95%)	(22.25%)	

[a] Since there were no statistically significant differences ($P > 0.05$) observed in the production of biomass of each components, the value expressed is the mean of three independent experiments. The values given in parenthesis are percent contribution of biomass of each component.

(52.270 t^{-1} ha) and *Ardisia tenera* (15.135 t^{-1} ha) the least. The accumulation of biomass was more in stems than other tree components. Variations in accumulation of biomass may be attributed to factors such as forest type and growing conditions (Francis, 1984; Ku et al., 1981). However, 10–40% more forest biomass accumulation has been reported in other measured tropical forests of the World (Hozumi et al., 1979; Anonymous, 1975; Rai, 1984; Kira et al., 1974; Jordan, 1981; Tanner, 1975; Prieston and Vanclay, 1988; Vanclay, 1989; Vanclay, 1991, 1992).

3.2. Nutrient concentration

Average nutrient concentrations of the four components of the tree species measured are given in Table 2. The highest concentration of different nutrients in the various biomass components was generally observed in

Table 2
Average nutrient concentration (±S.E) in different components of tree species in tropical seasonal rain forest in Xishuangbanna, China (mg g^{-1})

Nutrient	Components	Tree Species[a]							
		1	2	3	4	5	6	7	8
N	Leaves	10.5 ± 3.5	9.7 ± 2.5	9.3 ± 3.0	9.0 ± 2.9	8.8 ± 3.0	7.9 ± 1.5	7.5 ± 2.0	7.4 ± 2.0
	Branches	8.9 ± 2.0	8.2 ± 2.5	7.9 ± 4.0	7.0 ± 1.9	6.7 ± 2.5	6.5 ± 2.3	6.2 ± 1.5	6.2 ± 1.9
	Stem + Bark	8.2 ± 1.9	7.8 ± 3.4	7.4 ± 3.5	6.7 ± 2.0	6.4 ± 1.5	6.0 ± 1.9	6.0 ± 1.0	6.0 ± 1.5
	Root	7.7 ± 2.3	7.3 ± 3.0	6.9 ± 3.5	6.3 ± 1.5	6.0 ± 1.9	5.7 ± 2.0	5.5 ± 1.0	5.3 ± 1.0
P	Leaves	1.0 ± 0.60	1.0 ± 0.09	0.9 ± 0.08	0.9 ± 0.09	0.8 ± 0.08	0.8 ± 0.07	0.8 ± 0.07	0.8 ± 0.02
	Branches	0.8 ± 0.03	0.8 ± 0.04	0.8 ± 0.02	0.8 ± 0.01	0.7 ± 0.03	0.7 ± 0.01	0.7 ± 0.03	0.7 ± 0.01
	Stem + Bark	0.8 ± 0.03	0.8 ± 0.01	0.7 ± 0.02	0.7 ± 0.02	0.6 ± 0.03	0.6 ± 0.04	0.6 ± 0.02	0.6 ± 0.02
	Root	0.7 ± 0.01	0.7 ± 0.01	0.6 ± 0.01	0.6 ± 0.01	0.5 ± 0.01	0.5 ± 0.01	0.5 ± 0.01	0.5 ± 0.03
K	Leaves	10.6 ± 3.0	9.5 ± 2.5	9.0 ± 2.0	8.7 ± 1.5	8.2 ± 1.9	7.6 ± 1.5	7.5 ± 2.5	7.5 ± 2.0
	Branches	10.0 ± 3.1	8.9 ± 3.0	8.4 ± 2.1	7.8 ± 2.0	7.3 ± 2.0	6.7 ± 1.9	6.5 ± 2.5	6.4 ± 2.5
	Stem + Bark	8.9 ± 2.5	8.2 ± 2.5	7.9 ± 2.5	7.4 ± 1.9	6.9 ± 2.5	6.4 ± 1.5	6.3 ± 2.9	6.0 ± 2.9
	Root	8.4 ± 1.9	3.6 ± 1.9	7.3 ± 1.9	6.9 ± 2.0	6.4 ± 2.4	6.0 ± 2.0	6.0 ± 1.9	5.8 ± 1.5
Ca	Leaves	5.1 ± 1.0	4.4 ± 1.0	3.8 ± 1.0	3.3 ± 0.9	2.9 ± 0.9	2.3 ± 0.5	2.3 ± 0.8	2.2 ± 0.9
	Branches	4.3 ± 0.9	3.8 ± 0.9	3.1 ± 6.9	2.9 ± 0.8	2.3 ± 0.8	2.0 ± 0.8	2.0 ± 0.7	2.0 ± 0.8
	Stem + Bark	4.1 ± 1.2	3.9 ± 0.8	3.6 ± 1.0	3.0 ± 0.9	2.3 ± 1.0	1.8 ± 0.9	1.8 ± 0.9	1.7 ± 0.8
	Root	3.9 ± 0.8	3.6 ± 0.9	3.4 ± 0.7	2.9 ± 1.0	2.0 ± 0.9	1.6 ± 0.9	1.5 ± 0.8	1.5 ± 0.9
Mg	Leaves	5.4 ± 1.0	5.2 ± 1.0	4.9 ± 0.5	4.3 ± 0.8	3.7 ± 0.1	3.4 ± 0.8	3.2 ± 0.8	3.2 ± 1.0
	Branches	4.8 ± 0.9	4.6 ± 1.0	4.0 ± 0.9	3.8 ± 0.8	3.2 ± 0.9	3.0 ± 0.9	3.0 ± 0.5	3.0 ± 0.9
	Stem + Bark	4.6 ± 0.9	4.4 ± 1.0	4.3 ± 0.8	4.1 ± 0.1	3.3 ± 0.9	2.9 ± 0.8	2.9 ± 0.4	2.9 ± 0.5
	Root	4.3 ± 0.9	3.9 ± 0.9	3.5 ± 0.9	3.1 ± 0.1	2.7 ± 0.9	2.5 ± 0.9	2.5 ± 0.9	2.5 ± 0.9

[a] Each value expressed is the mean of the three independent experiments. Tree Species: 1. *Pometia tomentosa*, 2. *Barringtonia macrostachy*, 3. *Terminalia myriocarpa*, 4. *Gironniera subaequalis*, 5. *Cleidion previpetiolatum*, 6. *Mezzettiopsis creaghii*, 7. *Garcinia cowa* and 8. *Ardisia tenera*.

leaves, branches, stem and roots. The proportion of nutrient elements was in the order of K > N > Mg > Ca > P except for leaves, where the nutrient elements were found in the order of N > K > Mg > Ca > P. These are in general agreement with results for moist tropical forests of Ghanna (Greenland and Kowal, 1960) mountain rain forests in New Guinea (Edwards and Grubb, 1982), rain forests in north–east Australia (Stocker, 1983), loblolly pine stands in northern Lousiana (Lockaby and Adames, 1986), *Dendrocalamus hamiltonii* (Toky and Ramakrishnan, 1982), *Bambusa balcooa, Dendrocalamus strictus* and *Thyrostachys oliveri* (Tewari et al., 1994), *Bambusa bambos* (Shanmughavel, 1995) and *Acacia holosericea* (Anbhazhagan, 1998).

Of the cation concentrations, K was the highest. In this context, these tropical seasonal rain forests play an important role in the conservation of K because of their capacity for rapid uptake and accumulation (Shrivastava and Ulrich, 1978) which is analogous to Costa Rican wet forest sites in Central America (Ewel et al., 1981) or rain forests in north–east Australia (Stocker, 1983).

3.3. Nutrient uptake

The average annual nutrient uptake was obtained by multiplying the productivity of biomass components with their respective nutrient concentration (Tables 3–7). In this study, total accumulation of all nutrients was found to be 6167.7 kg ha^{-1}, out of which the contribution of N, P, K, Ca, and Mg were 2010.6, 193.3, 2123.8, 832 and 1005 kg ha^{-1}, respectively. It was observed that, on a unit area basis, the maximum amount of all nutrients was found in stems followed by branches, roots and leaves. Therefore the maximum loss of all nutrients occurred through stem harvest and among the nutrients the primary mineral loss was K followed by N, Mg, Ca, and P. However approximately 20–35% more accumulation of all nutrients has been reported for other forests such as lowland rain forests, Brazil; Ghanna; Panama; New Guinea and lower mountain rain forests at Puerto Rico (Whitemore, 1984). Since the annual nutrient uptake is usually followed by annual biomass expansion (average annual production), it increases linearly during the period of rapid growth and diminishes at maturity (Pritchett, 1979; Hilton, 1987).

Table 3
Nitrogen retained in different components of tree species in tropical seasonal rain forest in Xishuangbanna, SW China (kg ha^{-1})

Tree Species	Leaves	Branches	Stem	Root
(1) *Metzzettiopsis creaghij*	4.88 d	37.42 d	164.71 cd	40.76 c
(2) *Garcinia cowa*	6.92 e	48.79 e	161.81 c	35.92 a
(3) *Pometia tomentosa*	3.94 cd	36.48 d	301.89 g	85.54 cd
(4) *Ardisia tenera*	0.61 a	5.87 a	64.43 a	17.85 d
(5) *Barringtonia macrostachya*	2.72 b	25.76 bc	243.21 f	69.35 b
(6) *Terminalia myriocarpa*	7.29 e	26.86 bc	95.96 b	28.84 c
(7) *Gironniera subaequalis*	3.37 bc	30.23 c	174.47 e	45.34 b
(8) *Cleidien brevipetiolalum*	2.95 bc	23.49 b	170.23 de	45.91 bc
Mean	4.13	29.36	172.08	46.19
F-Statistics ($F_{7,16}$)	47.10**	62.38**	816.87**	39.21**

a–g Means followed by a common letter are not significantly different at the 5% level by DMRT.
** Significant at $P < 0.01$ level.

Table 4
Phosphorus retained in different components of tree species in tropical seasonal rain forest in Xishuangbanna, SW China (kg ha^{-1})

Tree Species	Leaves	Branches	Stem	Root
(1) *Metzzettiopsis creaghij*	0.49 d	4.04 d	16.47 c	3.58 cd
(2) *Garcinia cowa*	0.74 e	5.51 e	16.18 c	3.27 c
(3) *Pometia tomentosa*	0.38 c	3.28 c	29.33 f	7.69 g
(4) *Ardisia tenera*	0.07 a	0.66 a	6.44 a	1.68 a
(5) *Barringtonia macrostachya*	0.28 b	2.51 b	24.94 e	6.65 f
(6) *Terminalia myriocarpa*	0.71 e	2.72 b	9.04 b	2.51 b
(7) *Gironniera subaequalis*	0.37 c	3.46 c	18.23 d	4.32 e
(8) *Cleidien brevipetiolalum*	0.27 b	2.45 b	15.96 c	3.83 d
Mean	0.41	3.07	17.07	4.19
F-Statistics ($F_{7,16}$)	99.48**	85.15**	221.42**	197.77**

a–g Means followed by a common letter are not significantly at the 5% level by DMRT.
** Significant at $P < 0.01$ level.

Table 5
Potassium retained in different components of tree species in tropical seasonal rain forest in Xishuangbanna, SW China (kg ha^{-1})

Tree Species	Leaves	Branches	Stem	Root
(1) *Metzzettiopsis creaghij*	4.69 d	38.57 d	175.69 c	42.91 e
(2) *Garcinia cowa*	6.92 e	51.15 e	169.89 c	39.18 d
(3) *Pometia tomentosa*	3.98 c	40.99 d	327.67 g	92.22 g
(4) *Ardisia tenera*	0.62 a	6.06 a	64.43 a	19.53 a
(5) *Barringtonia macrostachya*	2.66 b	27.95 b	255.68 f	34.20 c
(6) *Terminalia myriocarpa*	7.06 e	28.53 b	102.62 b	30.51 b
(7) *Gironniera subaequalis*	3.60 c	33.69 c	192.69 e	49.66 f
(8) *Cleidien brevipetiolalum*	2.75 b	25.59 b	183.53 d	48.97 f
Mean	4.03	31.56	183.95	44.64
F-Statistics (F_7, 16)	99.48**	85.15**	221.42**	197.77**

a–g Means followed by a common letter are not significantly at the 5% level by DMRT.
** Significant at $P < 0.01$ level.

Table 6
Calcium retained in different components of tree species in tropical seasonal rain forest in Xishuangbanna, SW China (kg ha^{-1})

Tree Species	Leaves	Branches	Stem	Root
(1) *Metzzettiopsis creaghij*	4.69 d	38.57 d	175.69 c	42.91 e
(2) *Garcinia cowa*	6.92 e	51.15 e	169.89 c	39.18 d
(3) *Pometia tomentosa*	3.98 c	40.99 d	327.67 g	92.22 g
(4) *Ardisia tenera*	0.62 a	6.06 a	64.43 a	19.53 a
(5) *Barringtonia macrostachya*	2.66 b	27.95 b	255.68 f	34.20 c
(6) *Terminalia myriocarpa*	7.06 e	28.53 b	102.62 b	30.51 b
(7) *Gironniera subaequalis*	3.60 c	33.69 c	192.69 e	49.66 f
(8) *Cleidien brevipetiolalum*	2.75 b	25.59 b	183.53 d	48.97 f
Mean	4.03	31.56	183.95	44.64
F-Statistics (F_7, 16)	99.48**	85.15**	221.42**	197.77**

a–g Means followed by a common letter are not significantly at the 5% level by DMRT.
** Significant at $P < 0.01$ level.

Table 7
Magnesium retained in different components of tree species in tropical seasonal rain forest in Xishuangbanna, SW China (kg ha^{-1})

Plant Species	Leaves	Branches	Stem	Root
(1) *Metzzettiopsis creaghij*	2.10 d	17.27 d	79.61 c	17.88 ab
(2) *Garcinia cowa*	2.95 e	23.61 f	78.21 c	16.33 ab
(3) *Pometia tomentosa*	2.03 d	19.68 e	169.36 g	37.21 c
(4) *Ardisia tenera*	0.26 a	2.84 a	31.14 a	8.42 a
(5) *Barringtonia macrostachya*	1.46 bc	14.45 c	137.19 f	37.05 c
(6) *Terminalia myriocarpa*	3.84 f	13.60 c	55.53 b	14.63 ab
(7) *Gironniera subaequalis*	1.78 cd	16.41 d	106.76 e	22.31 b
(8) *Cleidien brevipetiolalum*	1.24	11.22 b	87.77 d	20.66 b
Mean	1.95	14.88	93.19	21.81
F-Statistics (F_7, 16)	60.15**	171.20**	1058.44**	9.20**

a–g Means followed by a common letter are not significantly different at the 5% level by DMRT.
** Significant at $P < 0.01$ level.

4. Conclusions

Located in the ecotone between east Asia, the Himalayas and Indochina (Continental SE Asia), the tropical seasonal rain forest in Xishuangbanna dealt with in this study shows a major influence of tropical features in the forest flora. Determining the nutrient content in the major trees of the tropical rain forests in Xishuangbanna, should lead to improvement in the nutrient loses from such sites as a result of harvesting and flow of nutrients within the ecosystem, for the development of effective and rational forest management strategies. The biomass studied revealed that *Pomatia tomentosa* had the greatest rate of dry matter accumulation (52.27 t ha^{-1}) and minimal rate in *Ardisia tenesa* (15.13 t ha^{-1}). The percentage distribution of nutrients

in different biomass components varied. The maximum amount of all nutrients per ha occurred in the stems followed by branches, roots and leaves. It is currently understood that much of the World's tropical rain forest exist on very poor soils and are only able to do so by retaining a high proportion of the available nutrients within the biomass. The proportion which is lost is replenished through nutrients imported to the site largely in rainfall. The disturbance of the rain forests by logging can disturb this mechanism and cause further impoverishment of the site. As the better quality forest is consumed and poorer areas are exploited, techniques have to be developed to reduce disturbance and conserve the nutrient regimes within the forest.

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13

A PRELIMINARY STUDY ON THE NATURAL BAMBOO FORESTS IN XISHUANGBANNA, SOUTHWEST CHINA

P. SHANMUGHAVEL AND MIN CAO

XISHUANGBANNA is famous in China for its diverse flora, fauna and beautiful landscape. It is estimated that about 5,000 species of higher plants (16 per cent of those in China) occur in this area of 19,200 km^2 (0.2 per cent of China's total area) (Li *et al*, 1984), of which nearly 1,000 species of wild plants can be directly utilised by the people. This area has one of the greatest diversity of species in China and is of great importance in the maintenance of regional biodiversity. In the early 1950s, about 60 per cent of the total area of Xishuangbanna was covered by forest. Recent investigation, however, revealed that this has declined greatly because of the rapid expansion of the local population and irrational exploitation of local forest resources since the end of the 1950s (Zheng, 1986).

Deforestation in Xishuangbanna has led to ecological problems in the local environment and agricultural development (Li *et al*, 1984) and also threatened local diversity. A survey revealed that work on tree species composition (Min Can *et al*, 1996), grasses, legumes and forage plants (Wu-Renrun, 1989), biomass production (Shanmughavel *et al*, 2000), nutrient cycling (Shanmughavel *et al*, 2000) of tropical seasonal rainforests in Xishuangbanna are reported.

The main objective of this investigation was to assess the natural bamboo species diversity in the typical forests of Xishuangbanna.

MATERIAL AND METHODS

Study Site

Xishuangbanna, south-west China, borders Laos and Myanmar (21° 09'-22° 33' N, 99° 55'-101° 50 E). Owing to the southward inclination of the Nu and Wuling mountains in the north and their eastward and westward extension, the terrain slopes from north to south. The Lancang

TABLE 1
Main Bamboo Forest Types in Xishuangbanna

	Forest Types	Distribution
	Fargesia sp. Forest	**Xishuangbanna**
Warm	*Yushania* sp. forest	Xishuangbanna
Bamboo	*Fargesia yunnanensis* forest	Xishuangbanna
Forest	*Chimonobambusa* sp. forest	Xishuangbanna
	Qiongzuea tumiclinoda forest	Xishuangbanna
	Sinocalamus affinis forest	Xishuangbanna
	Bambusa intermedia forest	South Yunnan
	Phyllostachys pubeascens forest	South Yunnan
	Ph. nigra var. henonis forest	South Yunnan
	Teinostachyum sp. forest	South Yunnan
	Chimonocalamus sp. forest	
Tropical	*Dendrocalamus membraneous* forest	South Yunnan
Bamboo	*D. giganteus* forest	Xishuangbanna
Forest	*D. yunnanensis* forest	South Yunnan
	D. sikkimensis forest	South Yunnan
	D. barbatus forest	Xishuangbanna
	Bambusa sinospinosa forest	Xishuangbanna
	Schizostachyum funghomii forest	Xishuangbanna
	Sch. pingbianensis forest	South Yunnan
	Cephalostachyum geragacila forest	South Yunnan
	Indosasa sinnica forest	Xishuangbanna
	Indosasa sp. forest	South Yunnan
	Ferrocalamus strictus forest	Xishuangbanna
	Melocalamus compactiflorous forest	Xishuangbanna
	Pseudostachyums polymor plum forest	Xishuangbanna
	Bambusa lapidea forest	Xishuangbanna
	Thynsostachya siamensis forest	South Yunnan
	Gigantochloa sp. forest	South Yunnan
	Dinochloa sp. forest	South Yunnan
	Leptocanna chinensis forest	

River with more than 20 tributaries, the upper course of the Mekong, flows through this area, resulting in many river valleys or small basins.

The climate of Xishuangbanna is dominated by the south-west monsoon with high rainfall from November to April, so there is a well-defined alternation of rainy and dry seasons. The mean temperature is 21.7° C, the mean temperature of the coldest month (January) is 15.5° C, annual

TABLE 2
Bamboo Genus Found in Xishuangbanna

No.	Genus	No. of Species			Percentage
		World	China	Yunnan	
1.	Teinostachyum	6	2	2	100
2.	Schizostachyum	70	7	4	57.1
3.	Lepiocanna	1	1	1	100
4.	Pseudostachyum	1	1	1	100
5.	Melocalamus	1	1	1	100
6.	Dinochloa	20	2	2	100
7.	Cephalostachyum	12	5	5	100
8.	Thyrsosauchys	2	2	2	100
9.	Bambusa	100	60	10	16.7
10.	Lingania	10	10	1	10
11.	Dendrocalamus	35	29	23	79.3
12.	Neosinocalamus	3	2	2	100
13.	Gigantochloa	30	6	6	100
14.	Indosasa	21	21	7	33.3
15.	Sinobambusa	17	16	2	42.1
16.	Qiongzhuea	3	3	1	33.3
17.	Chimonocalamus	19	19	8	42.1
18.	Phyllostachys	70	50	8	16.0
19.	Chimonocalamus	10	8	8	100
20.	Amplocalamus	8	8	3	37.5
21.	Neomicrocalamus	2	2	1	50.0
22.	Forgesia	76	75	41	54.7
23.	Yushania	47	43	22	51.2
24.	Pleoblastus	20	5	3	60.0
25.	Ferroalamus	1	1	1	100
26.	Indocalamus	30	15	2	13.3
27.	Monocladus	5	5	1	20

precipitation is 1,221 mm, of which 1,056 mm (more than 85 per cent) occurs in the rainy season and the minimum monthly rainfall is 9.4 mm (February).

VEGETATION ANALYSIS

The tropical forest's natural bamboo was surveyed on the basis of empirical approaches. The study area of several hectares (nearly 10 hectares) was sub-divided into 100 sub-plots (10 × 10 metres each) with corner posts. The bamboo found in each plot was recorded and the samples were

brought to the laboratory and identified by the Xishuangbanna Tropical Botanical Garden, Kunming Institute of Botany, the Chinese Academy of Sciences, Yunnan, China. The nomenclature of all the bamboo species in Xishuangbanna is according to Li *et al* (1984). On the basis of results, different bamboo forest types were established. The total number of different bamboo species under different genus were compared with world, China and Xishuangbanna.

RESULTS

The results of the preliminary investigation revealed that two major forest types occurred in the Xishuangbanna, namely, warm bamboo forest and tropical bamboo forest (Table 1). There are nine different species in the warm bamboo forest while in the tropical bamboo forest there are 21 different species.

The total of different species belonging to different genus identified in Xishuangbanna are presented in Table 2. The results revealed that 27 genus occurred in this forest which were compared with the rest of China and the world.

The results of the preliminary investigation revealed that Xishuangbanna forest harbours the maximum bamboo wealth of China. Further study is in progress.

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12

NUTRIENT CYCLING IN A TROPICAL SEASONAL RAINFOREST OF XISHUANGBANNA, SOUTH WEST CHINA—II. LITTER PRODUCTION AND NUTRIENT RETURN

P. SHANMUGHAVEL, ZHENG ZHENG, LIQUING SHA AND MIN CAO

LITTER on the forest floor, made up of various plant components (leaves, branches, twigs and bark), affects the moisture status of the top layer of soil and the water run-off pattern as well as nutritional aspects and site quality (Raizada and Srivastava, 1986). Litter fall and decomposition are two primary mechanisms by which the forest ecosystem's nutrient poll is maintained. The litter on the forest floor acts as an input–output system for nutrients (Das and Ramakrishnan, 1985), and the rate at which forest litter falls and subsequently decays regulate energy flow, primary productivity and nutrient cycling in forested ecosystems (Karmas, 1970; Waring and Schsinger, 1985). It is particularly important in the nutrient budget of tropical forest ecosystems on nutrient poor soils where vegetation depends on the recycling of nutrients contained in the plant detritus (Singh, 1968; Cole and Jhonson 1978; Pritchett and Fisher, 1987).

Many authors reported that species composition, density, basal area, age, structure (Stohlgren, 1988a), altitude (Reiners and Larg, 1987), latitude (Bray and Gorham, 1964) and season (Luizao and Schubartt, 1907) are factors that strongly influence litter fall dynamics in natural forests. Litter production by individual tree species in a natural forest stand is dependent on their dominance in the stand and the total amount reflects its stocking density (Kotwal and Mall, 1977).

In recent years, there has been an increase in the number of studies concerning litter dynamics, although a majority of these deal with temperate and/or homogenous forests (Das and Ramakrishnan, 1985; Pande and Sharma, 1986; Gill *et al*, 1987; Stohlgren, 1988a, 1988b; Harmon *et al*, 1990; Mohan Kumar and Deepa, 1992). The studies on litter production and mineral nutrient dynamics of tropical forest ecosystems are, however, few and far between (Harmera *et al*, 1978; Jordan *et al*, 1980; Luizao and Schubart, 1987; Pascal, 1988).

Hence, the main objective of this investigation was to assess the litter production and nutrient return behaviour of the tropical seasonal rainforests of Xishuangbanna in Southwest China.

MATERIALS AND METHODS

Physical Geography

Xishuangbanna, southwestern China, borders Laos and Myanmar (21°09'-22° 33' N, 99° 58'-101° 50' E). Owing to the southward inclination of the Nu and Wuliang Mountains in the north and their eastward and westward extension, the terrain slopes from north to south. The Lancang River with more than 20 tributaries, the upper course of the Mekong, flows through this area resulting in many river valleys or small basins.

The climate of Xishuangbanna is dominated by the southwest monsoon with high rainfall from November to April, so that there is a well defined alternation of rainy and dry seasons. The annual mean temperature is 21.7° C, the mean temperature of the coldest month (January) is 15.5° C; annual precipitation is 1,221 mm, but 1,056 mm of it (more than 85 per cent) occurs in the rainy season; the minimum monthly rainfall is 9.4 mm (February).

STUDY SITE

Xishuangbanna is on the northernmost edge of tropical Asia, where the tropical and temperate flora intermingle. This leads to an ecological mosaic of tropical vegetation represented by rainforest and subtropical vegetation by evergreen broad-leaved forest. However, the distribution of these forests is not continuous because of the mountainous topography.

This is the most luxuriant forest in Xishuangbanna and is mainly distributed in the wet valleys, usually with small streams or on the low hills and flats below 1,000 metres altitude. It is rich in species and has a complex forest canopy and structure. In a 1.04 hectare plot, 125 tree species (DBH >5cm) were recorded. The canopy is uneven and consists principally of mega phenerophytes over 40 cm, and in some communities trees such as *Shorea chinensis* with umbrella crowns emerge sparsely from the canopy up to 60 metres in height. The canopy trees usually develop strong buttresses for example, *Shorea chinensis*, *Terminalia myriocarpa*, *Pometia tomentosa*. *Ficus altissima* has aerial roots from the large branches. In the understory cauliflorus trees occur frequently such as *Baccaurea ramiflora*, *Ficus auriculata*, *Saurauia* species. Many species of algae, lichens, mosses and ferns as well as Araliaceae, Araceae, Piperaceae, Moraceae and Orchidaceae comprise the epiphytes and stranglers. The woody climbers are very common and include *Byttneria integrifolia*, *Gnetum montanum*, *Tetracera scandens and Tetrastigma planicaule*, some reaching the forest canopy.

VEGETATION ANALYSIS

The tropical seasonal rain forest vegetation analysis was done using random quadrat methods. The one hectare study area was subdivided into 100 subplots (10 ×10 m each) with corner posts. The standing vegetation of a unit was considered to be made up of trees, shrubs and herbs. Identity, height, DBH and canopy diameter were recorded for all trees in the plots. Shrubs and herbs including grasses were also recorded by name, height and cover in subplots under the forest canopy or plots in herbaceous communities. The nomenclature of all the species in Xishuangbanna is according to Li (1979) and were identified by the Xishuangbanna Tropical Botanical Garden and Department of Ethnobotany, Kunming Institute of Botany, The Chinese Academy of Sciences, Yunnan, China.

LITTER COLLECTION

The litter fall (composite of leaves, wood, reproductive material) was collected at monthly intervals during the period from July 1999 to June 2000. The collections were based on 20 litter traps of 1 m^2 randomly placed in the four replicated sub sites. Each trap was made with 1.5 mm nylon mesh and held 15 cm off the ground on wooden legs. This collection method is consistent with that recommended by Proctor (1983). The litter from each trap was taken to the laboratory and subsequently sorted into the following categories.

1. Leaves.
2. Small woody material (that is, bark, wood and branches less than 2 cm diameter).
3. Reproductive structures (that is, flowers, fruits and seeds).
4. Unclassified (that is, any material passing through a 2 mm sieve, insects, amorphous material, etc.).

Dry weights of each component were determined by drying to constant weight at 80° C and the mean value for each sub-site was worked out on a unit area basis (gm^{-2}). The diameters of the individual traps were used to determine litter fall on a unit area basis.

NUTRIENT ANALYSIS

The litter samples were pooled and milled for chemical analysis. Nitrogen and phosphorus were estimated as described by Armstrong *et al* (1976) using the Technician Auto analyser II (Gedko International UK). The sample was digested in a Kjeldathern digestion system KT-408 (Bonn) at 400° C for 3 hours. One–gram samples were digested in digestion tubes with both 2.5 g potassium sulphate and 5 ml H_2SO_4. After digestion and cooling, the digested samples were made up to ml with distilled water and used for analysis of N and P. The nutrients K.Ca and Mg were analysed using an atomic absorption spectrophotometer (Perkin-Elmer 5000, USA) after wet digestion of a 1-g sample with a triple acid mixture (10 ml conc. HNO_3, 4 ml HC 104 and 1 ml conc. HCl). The digested samples were filtered through Whatman No. 42 filter paper and made up to 100 ml with distilled water and this solution was stored and used for analysis (Isaac and Jonson, 1975) All analysis was performed on the average of three replicates.

RESULTS AND DISCUSSION

Litter Fall

Our study in the tropical seasonal rainforests of Xishuangbanna indicated profound seasonal variations in detritus fall. Leaf shedding was heavy during the winter periods ranging from October to January for all dominant species. Leaf litter was the major fraction (Table 1). About 46 percent of leaf fall occurred during this period. A dry season maximum litter fall in tropical seasonal forests is well known (Singh and Ramakrishnan, 1982; Patricia, 1992; Mohan Kumar and Deepa, 1922) and is an adaptation to moisture stress (Whitemore, 1975; Boojh and Ramakrishnan, 1982). However, the higher winter season fall is unusual and largely attributable to the dominant species *Pometia tomentosa*, *Barringtonia*, *Macrostchya*, *Terminalia myriocarpa*, *Gironniera subaequalis*, *Cleidion praipetiolatum*, *Mezzettiophsis creaghii*, *Garcinia cowa* and *Ardisia tenera*. Lower temperature conditions of the winter and dryness of the season (Longman and Jenik, 1974) may be contributing factors for greater litter fall during the winter; this would help improve light penetration to ground level of the otherwise closed canopy during the rainy season.

TABLE 1
Litter Production (t/ha) in Tropical Seasonal Rainforests inXishuangbanna, Southwest China

	Leaves	Wood	Reproductive Material	Unclassified	Total
January	0.7 ± 0.1	0.6 ± 0.1	0.01 ± 0.001	-	1.31
February	0.5 ± 0.5	0.3 ± 0.1	0.03 ± 0.005	-	0.83
March	0.4 ± 0.3	0.1 ± 0.5	0.08 ± 0.001	0.09 ± 0.001	0.67
April	0.4 ± 0.1	0.1 ± 0.5	0.01 ± 0.005	0.05 ± 0.001	0.56
May	0.3 ± 0.5	0.2 ± 0.3	0.01 ± 0.001	0.01 ± 0.001	0.52
June	0.4 ± 0.3	0.2 ± 0.1	0.01 ± 0.003	0.01 ± 0.001	0.66
July	0.3 ± 0.1	0.1 ± 0.5	0.05 ± 0.001	0.03 ± 0.005	0.48
August	0.3 ± 0.3	0.1 ± 0.5	0.01 ± 0.002	0.06 ± 0.004	0.47
September	0.6 ± 0.3	0.2 ± 0.5	0.02 ± 0.003	0.01 ± 0.001	0.83
October	0.6 ± 0.2	0.4 ± 0.8	0.08 ± 0.001	0.03 ± 0.003	1.11
November	0.7 ± 0.1	0.5 ± 0.8	0.09 ± 0.003	0.04 ± 0.001	1.33
December	0.7 ± 0.2	0.6 ± 0.1	0.09 ± 0.001	0.02 ± 0.003	1.41

Leaves provide the bulk of total litter fall with 58 per cent followed by wood (33 per cent), reproductive material (5 per cent), unclassified (4 per cent), to the total litter production. However other workers reported more contribution of leaf litter to the total in different tropical forests: 62.4 per cent (Bray and Gorham, 1964); 71 per cent (O'Neill of De Angelis, 1980); 64.5 per cent (Cezar, 1988); 62.6 per cent (Maguro *et al*, 1979); 62 per cent (Pagamo, 1989a). Meentmeyer (1982) suggested that 70 per cent of the total litter produced by forests worldwide will be leaf matter.

The higher litter production in the tropical seasonal rainforests of this study (10 $t.ha^{-1} y^{-1}$) is comparable with the tropical lowland dipterocarp forest 0.6 to t $ha^{-1} y^{-1}$ (Yoda, 1978); tropical forest of Zaire 12.3 $t.ha^{-1} ya^{-1}$ (Laudelhoud and Mayer, 1954); semi-deciduous forests of Cameroon 13.5 $t.ha^{-1} yr^{-1}$ (Nicholas *et al*, 1995); forest over limestone, Sarawak, Mulu 10.4 $t.ha^{-1}y^{-1}$ (Anderson *et al*, 1983); tropical montane forests of Colombia 10.1 $t.ha^{-1}y^{-1}$ (Jenny *et al*, 1949), montane rainforests in Columbia 11 $t.ha^{-1}y^{-1}$ (Jenny *et al*, 1949), sacred grove climax forest at Cherrapunji, 11.7 $t.ha^{-1}y^{-1}$ (Khiewtarn and Ramakrishnan, 1993) and tropical Australia (Brassel *et al*, 1980). In

TABLE 2
Nutrient Concentration in Litter Components (mg g–1)

Nutrient	Leaves	Wood	Reproductive Material	Unclassified
N	9.1 ± 4.0	4.4 ± 0.1	5.8 ± 0.1	6.7 ± 1.5
P	0.8 ± 0.05	0.3 ± 0.03	0.5 ± 0.04	0.6 ± 0.04
K	6.5 ± 4.5	4.5 ± 0.5	4.8 ± 1.0	5.5 ± 1.5
Ca	4.7 ± 4.0	3.5 ± 0.3	4.2 ± 0.5	4.5 ± 0.8
Mg	5.0 ± 5.0	4.0 ± 0.5	3.5 ± 0.9	4.0 ± 1.0

TABLE 3
Nutrient Return Through Litter (t/ha^{-1})

Nutrient	Leaves	Wood	Reproductive Material	Unclassified	Total
N	0.53	0.17	0.03	0.02	0.75
P	0.05	0.01	0.002	0.002	0.06
K	0.35	0.14	0.02	0.02	0.53
Ca	0.23	0.10	0.02	0.01	0.36
Mg	0.29	0.13	0.01	0.01	0.44

contrast to, this study comparatively lower litter fall was reported in some tropical lowland forests: 5.7 to 8.1 $t.ha^{-1}y^{-1}$ (Bernhard, 1970); 4.7 $t.ha^{-1}y^{-1}$ (Hopkins, 1966; Medge, 1965); 5.6 to 7.8 $t.ha^{-1}y^{-1}$ (Anderson *et al*, 1983); 5.4 to 7.5 $t.ha^{-1}\ y^{-1}$ (Gong and Org, 1983).

The favourable temperature and rainfall conditions prevailing in our study area in Xishuangbanna and the concomitant higher primary productivity can account for this higher amount of litter production, because yearly litter yield is primarily a function of the annual synthesis of organic matter as foliage and other components (Bray and Gorham, 1964; Tadaki, 1966; Das and Ramakrishnan, 1985). However, despite the higher primary productivity and total litter fall, leaf litter fractions were comparable with the values reported in the literature (Klinge, 1977; Frankan *et al*, 1979; Luizao and Schubart, 1987).

Composition of the litter is regarded as a measure of the intrinsic quality (decomposability) and environmental characteristics of the soil and climate, which in turn, affect the release of the important nutrient elements through decomposition. The highest concentration of different nutrients in the various biomass components was generally observed in leaf, wood, unclassified and reproductive parts (Table 2). The proportion of nutrient elements in leaves and wood were in the order of N>K> Mg> Ca>P, whereas in reproductive parts and unclassified were in the order of N>K>Ca>Mg>P while many authors have shown a relationship between nutrient concentration in plant tissue and rate of litter decomposition (Tanner, 1981; Mellillo *et al*, 1982).

The comparative amounts of N, P, K, Ca and Mg recycled through the litter fall are tabulated in Table 3. It indicated that maximum nutrient return was through leaf litter (68 per cent) followed by wood (25 per cent), reproductive material (4 per cent) and unclassified (3 per cent). Similar results were observed in different forest tree species (Srivastava *et al*, 1972; Rozanov and Rozanov 1964; Kramer and Kozlowski, 1960; Longman and Jenik, 1974). The results of the present study revealed that tropical rainforests returns substantial quantities of N, K, Mg, Ca and P through litter fall. The wood, reproductive parts and other unclassified material collected and removed for various other uses therefore caused a great drain of nutrients. The results also point to the necessity of precautionary measures to maintain the nutrient status of the soil in these tropical seasonal rainforest ecosystems.

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XI. WORLD FORESTRY CONGRESS
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Antalya, 13 22 / 10 / 1997

WFC Central Coordinating Unit
FAO Forestry Department
Viale delle Terme di Caracalla
00100 Rome (Italy)

FO 7 12.1

Date: 3 April 1997

Dear Mr. Shanmughavel,

After review of your voluntary paper, the Scientific and Technical Committee of the XI World Forestry Congress has decided to invite you to make a brief presentation of your paper entitled:

Plantation bamboo for sustainable productivity

The abstract of your paper will be translated into the four languages of the Congress (English, French, Spanish and Turkish).

We would appreciate it if you could inform us as soon as possible whether you will be able to participate in person in the Congress and present your paper.

We wish to thank you for your interest and support to the XI World Forestry Congress and look forward to seeing you in Antalya in October.

Best regards,

Yours sincerely,

L.S. Botero
Associate Secretary-General
XI World Forestry Congress

Mr. P. Shanmughavel
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COMMONWEALTH FORESTRY ASSOCIATION
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2 September 1997

Dear Mr Shanmughavel,

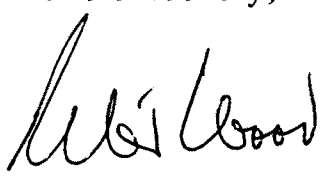
REPORT ON THE COMMONWEALTH FORESTRY CONFERENCE

Many thanks for your report on your attendance at the conference which, as you know, was supported by funds from the Canadian International Development Agency, and/or the Commonwealth Foundation.

The individual reports will be included with the CFA's final report to the donors.

Thank you also for your inputs to the conference sessions at Victoria Falls and I hope you have taken up your work again having benefitted from the contacts you made at the conference and from the debates in which you took part.

With best regards,
Yours sincerely,



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Dr. P. Shanmughavel, M.Sc. M.Phil, Ph.D
Bharathiar University
Coimbatore, India

Dear Mr. Shanmughavel,

I am pleased to inform you that, after review by the Scientific National and International Program Committee, the papers entitled: "Methodology to evaluate the productivity and nutrient dynamics in bamboo plantations" and "Introduction of bamboo in social forestry" have been accepted without any reservations, "Studies for growth and development of culms in plantation bamboo" has been accepted for poster session. All of them for presentation at the V International Bamboo Congress and the VI International Bamboo Workshop. In addition, we expect to publish the written paper in the conference proceedings which will be distributed to all congress attendees shortly after the Congress.

As stated in the "Second Announcement: General Information and Key dates", all full papers are due by August 31, 1998. It is critical that all papers are received prior to this date with the Registration Fee, in order to schedule your presentation in the Final Program. Guidelines for the preparation of the manuscript are enclosed. Please e-mail your paper or send us a printed copy and diskette (WIN 95) by air mail to:

Dr. Jorge Gutiérrez
Executive Director - VI-IBW/V-IBC
P. O. Box 21-1350
San Sebastián, Costa Rica
e-mail: pbambu@sol.racsa.co.cr

For further information you can visit our web site: http://www.funbambu.or.cr

We will appreciate acknowledge receipt of this letter (e-mail or fax (506) 226-4848). Please indicate who will be the presenting author (if applicable) and what type of audio-visual equipment will be needed for your presentation (slide, overhead, video beam, VHS -only NTSC-, etc.)

Cordially yours,

Dr. Jorge Gutiérrez
Executive Director

Enc. as indicated

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To

Dr. P. Shanmughavel et al
Dept. of Environmental Sciences
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Tamil Nadu, India

Dear Dr./ Prof.,

Your Abstract entilled" Evaluation of Bamboo plantations Raised from In Vitro plants in Tamil Nadu, India. ..... has been accepted for presentation in the 10th Bangladesh Botanical Conference, (November 12-14, 1999). The detail programme will be given to you during Registration.

Please inform us your date of arrival including flight No. and time of your arrival at the Zia Internatinal Airport.

We will provide local hospitality. Since we have not received any grant, we are sorry to mention that we are unable to provide any Air fare. I wish to see you in the Confrerence.

Thanking you.

Yours Sincerely

22.9.99

(Prof. A. K. M. Nazrul-Islam)
Secretary General
Bangladesh Botanical Society

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October 3, 1999

Dr. P. Shanmughavel
Department of Botany
Bharathiar University
Coimbatore, Tamilnadu
641 046 India

Dear Dr. Shanmughavel:

Thank you very much for your revised summary "Biomass production in an age series of *Bambusa bambos* plantations". I am pleased to inform you that it has been accepted for presentation as a poster in the IUFRO Division 1 poster program during the IUFRO 2000 World Congress in Kuala Lumpur, Malaysia in August 2000.

I request that you use this letter in support of your application for the Scientist Assistance Program, and hope to have the opportunity to meet you during the Congress next year.

With best wishes,

Dr. John A. Parrotta
Deputy Coordinator, IUFRO Division 1
Division 1 CSC representative

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Tree stand enhanced the soil moisture content to 2.8% from that of in the open site (0.7%). This ameliorative effect of tree stands caused proliferation of soil microflora, which serve as an index of site enhancement Increased bacterial population were noticeable under tree stands (5.3 x 106 per gm. of soil) as compared to the barren soil (1.8 x 106 per g soil). In general the treeless site supported low population (12 x 105 per g soil) of actinomycetes compared to the afforested site (21 x 105 per g soil). Similarly, the soils under tree stand harboured more fungal population (21.3 x 104 per g soil) than the barren soil (13.7 x 104 per g soil).

Biomass Production in an Age Series of *Bambusa bambos* Plantations

Piramanayag Shanmughavel, K. Francis
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Keywords: Biomass, age series, *Bambusa bambos*. Plantations mean periodic increment, net primary production.

Bamboo is one of the most useful plants known to mankind and approximately 2.5 billion people, mostly the poor in developing counties, depend on it for a wide range of uses and livelihoods. Sustained availability can be ensured only by raising extensive bomboo plantations. The growth and biomass production in age series (1-10 years) of *Bambusa bambos* plantations were studied and compared with its growth in natural and plantation stands. Culm recruitment was monsoon dependent and was enhanced by light rains preceding the onset of monsoon. The average daily height growth was 30 cm and independent of monsoon rainfall.

In order to estimate the total biomass in relation to organic productivity, 15 culms were randomly selected from each age group. For reasons of economy the rhizome was excavated only from three in each age group. After felling, the total height of each culm, diameter at breast height (DBH), basal area and number of nodes were measured and subdivided into leaves, branches, culm and rhizome. Fresh weight of components was estimated in the field and sub-samples from each component was brought to the laboratory in plastic bags. The sub-samples were then oven dried at 103 + 2°C at constant weight. From the oven dry weight of the samples the total standing biomass of each age group was calculated by multiplying the total number of the bamboos of different ages with the average dry weight of the sample.

There was linear increase of the total biomass of all compartments with the age of the plantations. Biomass was distributed between culms (81%), branches (14%), leaves (1%) and rhizome (4%). The total biomass ranges from 2.3 t/ha (1 year) to 297,9 t/ha (6 years) and then decreased to 15,6 t/ha (10 years). The number of culms produced per clump its height and DBH was found increased up to 6 year, later it found decreased. Ultimately the accumulation of biomass also decreased after 6 years. The mean annual biomass production was 49,6 t/ha/year over the 6 period. The mean periodic increment and net primary production was highest in the 5 year, during which a peak of 124 t/ha/year in net primary production was obtained.

Changes in Plant Species Diversity in a Restoration Sequence of *Quercus variabilis* Forest Stands in Baotianman Mountain

Zuomin Shi, Cheng Ruimei
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FAX: 0086-10-62881937, Email: Shizm@fee.forestry.ac.cn

Changes in plant species diversity in a restoration sequence of *Quercus variabilis* forest stands in Baotianman Mountain were studied. The result show that species richness and species diversity indices of different layers in forest stands with different restoration time are as follows: herb layer>shrub layer>tree layer. Most differences between species diversity of tree layer, shrub layer and herb layer in the forest stands were not significant. Only differences between species richness of tree layer and herb layer and that of shrub layer and herb layer were significant. Differences of tree species diversity among the forest stands were more significant, differences of shrub species diversity were significant, and differences of herb species diversity were not significant.

Seedling Survival and Growth of Canopy Trees Across Openings of a Sri Lankan Rain Forest.

B. M. P. Singhakumara, P. Mark S. Ashton
University of Sri Jayawardenapura, Department of Forestry and Environmental Science,
Nugegoda, Sri Lanka
Email: singha@eueka.lk

The basis for the management of native forests is an understanding of the micro-site requirements necessary for satisfactory regeneration

BANGLADESH ASSOCIATION FOR PLANT TISSUE CULTURE

4th International Plant Tissue Culture Conference

1 - 3 November, 2001, Dhaka, Bangladesh

C/o. Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh

Phone: 88-02-508614, Fax: 88-02-8615583, E.mail: baptc@bd.drik.net

July 18, 2001

Dr. P. Shanmugahvel
Research Scientist
Department of Botany
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Coimbatore - 641 046
INDIA
E-mail: shanvel_99@yahoo.com

Subject : Invitation to attend the 4th International Plant Tissue Culture Conference, Dhaka 1-3 November, 2001

Dear Dr. Shanmugahvel,

I am pleased to inform you that your abstract entitled "Mass propagation of Bambusa bambus through macroproliferation for raising industrial and commercial plantation" has been accepted for presentation in the forthcoming 4th International Plant Tissue Culture Conference to be held at Dhaka from 1-3 November, 2001. On behalf of the organizing committee I am most cordially inviting you to attend this conference and present your papers. I may mention that we shall arrange your local hospitality during the conference. Unfortunately due to fund constraints it will not be possible for us to provide you travel grants. I hope you may be able to arrange travel grants from your university or from any other donor agencies.

Looking forward to welcome you at Dhaka during the conference.

With kind regards.

Yours sincerely,

(Dr. M. Imdadul Hoque)
Secretary, Organizing Committee
4th International Plant Tissue Culture Conference
Web page: www.baptc.org

XIV International Plant Nutrition Colloquium

HANNOVER, GERMANY July 27 - August 3, 2001

Prof. Dr. Walter Horst
IPNC Secretariat c/o Institute of Plant Nutrition
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Dear Dr. Shanmughavel,

it is my pleasure to inform you, that your submitted proposed contribution to the International Plant Nutrition Colloquium 2001 in Hannover :
"The dynamics of nutrients in a Bamboo (Bambusa bambos) plantations",
Code No.: S11 A493
has been accepted for **poster** presentation. We have allocated your paper to Symposium **11.** Please confirm that you are the presenting author and make sure that you register.

Please let me express very clearly that there is no quality ranking between oral and poster presentations. Given the fact that in each of the 12 symposia only 6 oral presentations (out of 30-120) are possible, many presentations that appeared to us as particularly appropriate for oral presentation have to be presented as posters. Consequently we will allocate a substantial part of time of the Colloquium to the poster viewing and presentation. Specific thematically bundled poster sessions will be organised giving each poster presenter the opportunity to briefly (2 min maximum) introduce his poster orally.

Two pages extended abstracts of all accepted papers (no difference between oral and poster presentations) are included into the Conference Proceedings published by Kluwer Academic Publishers. Specific instructions will be distributed with the Final Circular. Please contact our web site for updated information regarding publications and registration. The extended abstracts have to reach the IPNC secretary in the required format not later than **31. January**. Papers not meeting this deadline will not be included into the Proceedings.
In further correspondence with us please use your "Code-No.".

Authors requesting financial support will be informed about the prospects and magnitude of support, which can be expected.

Looking forward to your contributions and meeting you in Hannover.

Best regards

Walter Horst

1ST WORLD CONGRESS OF AGROFORESTRY

Working Together for Sustainable Land-use Systems

27 June – 02 July 2004 • Orlando, Florida, USA

Conference Web Site: www.conference.ifas.ufl.edu/wca

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November 25, 2003

DR. P. SHANMUGHAVEL
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Bhrathiar University
Coimbatore 641 046
INDIA
Telephone:
Fax:

Dear DR. P. SHANMUGHAVEL,

We would like to extend an invitation for you to attend the **1st World Congress of Agroforestry (WCA)** to be held in Orlando, Florida, USA from 27 June through 02 July 2004. As you are aware, agroforestry is receiving increasing attention as a sustainable land management option the world over because of its ecological, economic, and social attributes. The objective of the Congress is to provide a global forum for professionals to share knowledge, experiences, and ideas for evaluating the progress of agroforestry, and to develop strategies for research, education and training.

As an agroforestry professional, your participation will greatly enhance the content of the program. Furthermore, the congress will provide numerous opportunities for you to engage in discussions with other agroforestry researchers, high-ranking government officials, practitioners, extension agents, and students from throughout the world. We trust your organization and country will support this endeavor and finance your travel and participation to the congress.

Sincerely,

MEdge

Maryann Edge
Invitation Letter Liaison

DEVI AHILYA VISHWAVIDYALAYA, INDORE

SCHOOL OF LIFE SCIENCE
VIGYAN BHAWAN,
Takshashila Campus, Khandwa Road,
INDORE-452 001 (M.P.) INDIA.
Phone : 0731-467029

National Symposium on Plant Physiology and Biochemistry in Relation to Agriculture and Environment

[February 15 - 17, 1999]

Receipt of the abstract entitled Litter production and nutrient return in Agroforestry System

by P. Sa Shanmughavel and K. Francis Coimbatore.

is thankfully acknowledged. The abstract has been accepted for oral / ~~poster~~ presentation. IV-02

Date : 5/1/99

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National Symposium

Convenor,
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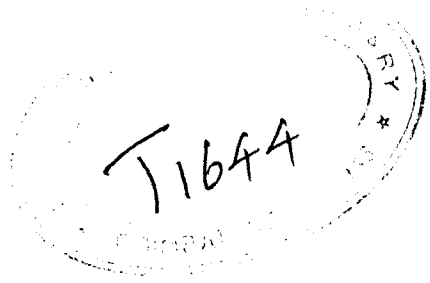
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